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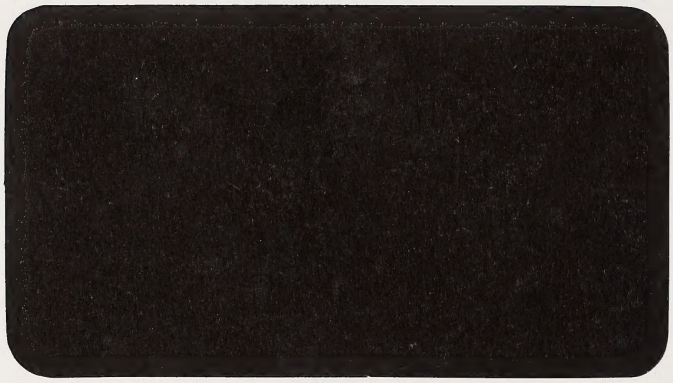
WATER QUALITY OF THE BATTLE RIVER

TECHNICAL REPORT

Alberta
ENVIRONMENT



WATER QUALITY OF THE BATTLE RIVER

TECHNICAL REPORT

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PREFACE

This report documents results of water quality surveys conducted in the Battle River in 1989 and 1990.

No further water quality sampling has been undertaken by Alberta Environment on the Battle River in Alberta since that time. However, the long-term monitoring program carried out by the Prairie Provinces Water Board at Unwin, Saskatchewan, has continued. Results of this long-term sampling program indicate that several water quality attributes do not meet PPWB objectives in the lower reaches of the Battle River. Low dissolved oxygen levels and high sodium, total dissolved solids, iron and manganese concentrations are typical for the lower Battle River, especially during the winter months; while high copper, zinc and fecal coliform bacteria are not uncommon during the open water period. These patterns of non-compliance with PPWB objectives have remained fairly unchanged since 1989 (refer to table). This suggests that water quality information from 1989 – 1990 is still representative of current conditions in the Battle River.

Although large municipalities still discharge their treated municipal effluent to the Battle River or its tributaries, some have upgraded their treatment system considerably and are now achieving much better effluent quality. In particular, the City of Camrose has reduced its phosphorus loading to the river considerably by upgrading its lagoon treatment system. Currently, the town of Ponoka is involved in a similar upgrading process, while the town of Stettler is enhancing their system by utilizing an engineered wetlands treatment process.

Water Quality of the Battle River at Unwin
Compliance with Prairie Provinces Water Board Objectives (PPWBO)
(based on PPWB data for the period 1989 to and including 1997)

	PPWBO (*)	1989	1990	1991	1992	1993	1994	1995	1996	1997
Dissolved Oxygen	6.0	3 (**)	3	3	2	3	4	4	4	0
pH	6.5 to 9.0	0	0	0	0	0	0	0	0	0
NO_2+NO_3 (as N)	10.0	0	0	0	0	0	0	0	0	0
Ammonia, Total (as N)	pH and temp	0	0	0	0	0	0	0	0	0
Total Dissolved Solids	500	8	5	5	6	9	11	10	8	8
Sodium (diss)	100	9	5	5	7	9	11	11	8	5
Fluoride (diss)	1.5	0	0	0	0	0	0	0	0	0
Sulphate (diss)	500	0	0	0	0	0	0	0	0	0
Chloride (diss)	100	0	0	0	0	0	0	0	0	0
Chromium (diss)	0.011	0	2	0	0	1	0	0	1	0
Manganese (diss)	0.05	3	4	2	0	3	ND	ND	ND	1
Iron (diss)	0.3	3	2	0	1	1	ND	ND	ND	0
Cobalt (total)	0.05	0	0	0	0	0	0	0	0	0
Nickel (total)	0.1	0	0	0	0	0	0	0	0	0
Copper (total)	0.004	1	4	4	3	4	4	2	5	4
Zinc (total)	0.03	0	1	0	0	1	0	0	2	1
Arsenic (diss)	0.05	0	0	0	0	0	0	0	0	ND
Boron (diss)	5.0	0	0	0	0	0	0	0	0	0
Selenium (diss)	1.0	0	0	0	0	0	0	0	0	ND
Aluminum (total)	5.0	0	0	0	0	0	ND	ND	ND	0
Cadmium (total)	0.001	0	0	0	0	1	0	0	1	1
Barium (total)	1.0	0	0	0	0	0	0	0	0	0
Lead (total)	0.007	0	1	0	0	1	0	0	2	1
Fecal Coliform Bacteria	100/100mL	0	1	0	2	2	4	2	2	2

* Units in mg/L unless otherwise noted

** Numbers indicate how many of the 12 monthly samples did not meet objectives in any one year

ND = No Data

EXECUTIVE SUMMARY

In 1989, Alberta Environment began field studies to monitor water quality in the Battle River from its headwaters to its confluence with the North Saskatchewan River in Saskatchewan. The purpose of this study was to provide an overview of the water quality in the river for the time period studied. The Battle River originates in Battle Lake, east of the foothills and flows in an eastward direction. It is a small river, which unlike the North Saskatchewan River, does not receive mountain snowmelt, but is fed only by local surface runoff and groundwater inputs. Consequently, river flows are low except during spring runoff or after heavy rains. Samson Lake, Driedmeat Lake and the Forestburg Reservoir, which are located on the Battle River, dampen seasonal changes in river flow and influence downstream river water quality. More than two-thirds of the population lives in the upper portion of the basin and nearly half of the population lives in large urban centers (i.e., Lacombe, Wetaskiwin, Ponoka, Stettler, Camrose, and Wainwright). The economy of the basin is almost exclusively based on agriculture, natural resource industries and the supporting service sector. Most municipalities, including all the large ones, discharge their wastewater to the river or its tributaries. Municipal discharges and discharges of cooling water by Alberta Power Ltd. to the Forestburg Reservoir represent the main point sources of effluent to the Battle River.

STUDY OBJECTIVES

There were five main objectives to the water quality study initiated in 1989:

1. To characterize spatial, seasonal and long-term changes in the river's water quality.

2. To characterize natural and human factors which affect the general water quality of the river such as point sources (tributaries, effluents) and non-point sources (diffuse runoff, groundwater).

3. To evaluate the short-term, local effects on water quality of spring and fall municipal discharges.

4. To compare present and historical water quality data with Alberta Ambient Surface Water Quality Interim Guidelines (AASWQIG), Canadian Water Quality Guidelines (CWQG) and Prairie Provinces Water Board Objectives (PPWBO) for the Battle River.

5. To document spatial and temporal trends in aquatic invertebrate community composition.

STUDY DESIGN

Thirteen synoptic surveys of the river and its tributaries were carried out between May 1989 and October 1990. Samples were collected at 15 mainstem and 15 tributary sites from the headwaters to the confluence with the North Saskatchewan River. A comprehensive list of physical, chemical and biological characteristics was monitored.

Additional water quality samples were collected from the Battle River during the discharge of wastewater from the Ponoka lagoon in spring and fall of 1990. Aquatic invertebrate samples were collected at mainstem sites in spring and fall of 1989.

Data from 1989-1990 were supplemented by information from other sampling programs to evaluate material loads from municipal effluents and long-term trends in the water quality of the Battle River.

GENERAL WATER QUALITY

From the headwaters to the confluence with the North Saskatchewan River there is a gradual increase in turbidity, non-filterable residue, specific conductance, alkalinity, total dissolved solids, and most major ions. These increases are mainly the result of natural factors such as river flows, tributary loading, inflow of groundwater and contribution of materials from the drainage basin. Although calcium is the dominant cation upstream of Samson Lake, sodium is dominant in the rest of the basin. Bicarbonate is the dominant anion in the entire basin, but sulphate and chloride become increasingly important in a downstream direction. These changes in ionic dominance reflect changes in surficial geology and groundwater quality. Municipal discharges also contribute substantial amounts of salts to the Battle River.

Nutrient levels are highest between Samson Lake and the Forestburg Reservoir; they decline or stabilize further downstream. This longitudinal pattern reflects the influence of point and non-point sources upstream of the reservoir and dilution by groundwater downstream of the reservoir. However, it is also indicative of the influence of lakes, especially Driedmeat Lake which, depending on season and river flows, can act as sinks or sources of nutrients. In response to the high concentration of plant nutrients, macrophyte and phytoplankton growth is abundant in the upper portion of the river.

Many water quality variables show distinct seasonal patterns in the Battle River. In rivers, the amount of particulate matter usually increases as flows increase. Consequently, constituents typically associated with particulate matter (e.g., non-filterable residue, total and particulate nitrogen, phosphorus and carbon, many metals) reach the highest concentrations during periods of high river flow. In contrast, concentrations of many dissolved substances, such as major ions, are highest at low flows. Aquatic plants greatly enhance diurnal and seasonal fluctuations in dissolved oxygen. Plant metabolism also influences the seasonal changes in nutrient concentrations. Some seasonal aspects of water quality are influenced by the availability of dissolved oxygen in the water column. For example, iron and manganese, which become highly soluble under anoxic conditions, occur generally at highest concentrations under ice cover. However, high iron and manganese concentrations during the open water season in highly productive stretches of the river indicate that diurnal fluctuations in dissolved oxygen concentrations may also induce sediment release of these metals.

Long-term data from the Battle River at Unwin, Saskatchewan, indicate that concentrations of some water quality constituents have changed significantly over the period of record (i.e., 1974 – 1990). Some constituents such as non-filterable residue, turbidity, dissolved organic carbon, particulate organic carbon, and aluminum have increased in concentration, while others such as true colour, hardness, total dissolved solids, sodium, magnesium, sulphate, total nitrogen, dissolved nitrogen, phenolics and alpha-BHC have declined. In most cases, changes though statistically significant are slight and their cause is not known. Annual river discharge has not changed significantly over time.

HUMAN INFLUENCES

Most municipalities in the Battle River basin discharge their treated wastewater discontinuously (spring and/or fall). Although significant increases in river nutrient and major ion

concentrations persisted only during the passage of individual wastewater plumes, the total municipal load to the Battle River is substantial and contributes to the river's eutrophic nature. In contrast, municipal discharges did not influence river metal concentrations or bacteria counts significantly.

There were distinct seasonal differences in effluent quality. Nutrient levels were much higher in spring. At that time, ammonia levels in some effluents were high enough to increase river concentrations above safe levels for aquatic life.

Diffuse sources of nutrients such as natural erosion and weathering and runoff from agricultural and cleared land also affect river water quality. Their contribution is difficult to quantify, especially on a basin-wide basis. A preliminary assessment indicated that in the Battle River phosphorus contributions from point and non-point sources are of the same order of magnitude.

Discharges of cooling water by Alberta Power Ltd. increased water temperatures of the Forestburg Reservoir. When river flows were high a lot of warm reservoir water moved downstream and elevated Battle River water temperatures by several degrees Celsius over ambient temperatures. In winter the ice-free reservoir represented a major zone of re-aeration and had a beneficial effect on some aspects of river water quality (e.g., increased dissolved oxygen, decreased dissolved metals concentration and increased nitrification processes). Concentrations of several metals including aluminum, arsenic, copper, nickel, iron, and zinc were slightly elevated downstream of the reservoir.

COMPLIANCE WITH WATER QUALITY GUIDELINES

According to Canadian Water Quality Guidelines, Alberta Ambient Surface Water Quality Interim Guidelines, and Prairie Provinces Water Quality Objectives, the quality of Battle River water has many limitations for various uses. Low dissolved oxygen and high ammonia levels present the most severe limitations for the protection of aquatic life, but many other water quality characteristics exceed recommended levels (e.g., various forms of nitrogen, total phosphorus, temperature, pH, phenolic compounds and many metals).

Battle River water is generally suitable for livestock watering, but high sodium and manganese levels and high fecal coliform bacteria counts restrict its value as irrigation water. High total coliform bacteria counts, colour levels and excessive growth of rooted plants and algae limit the recreation potential or aesthetic value of the river water.

For many water quality variables, non-compliance occurred at high river flows when materials from diffuse sources, including the river's sediment, is transported. However, for other water quality variables, non-compliance was directly related to municipal discharges (ammonia, nitrite) or to the discharge of cooling water (temperature).

AQUATIC INVERTEBRATES

As in most other rivers, flow velocity and substrate type determines to a large extent the type of fauna which exists in the Battle River. In this river, flows are usually so sluggish that most invertebrates are adapted to standing water. Worms, midges, clams, and scuds, which are common in the Battle River, are also encountered in lakes. Substrate preferences were noticeable in spring: muds rich in organic matter, upstream of the Forestburg Reservoir, contained larger numbers of organisms than clean-looking, shifting

sands downstream of the reservoir. The largest diversity of invertebrates was encountered in macrophyte stands along the river's edge. These stands offer food and shelter to a large variety of aquatic organisms including worms, insects, molluscs, and crustaceans. Municipal discharges with high ammonia concentrations may reduce invertebrate numbers and diversity. However, chronic effects of eutrophication such as excessive plant growth and extreme variation in dissolved oxygen concentration likely impose more limitation on the type of invertebrate fauna that lives in the Battle River.

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ABBREVIATIONS

d/s	downstream
u/s	upstream
AEC	Alberta Environmental Center
AASWQIG	Alberta Ambient Surface Water Quality Interim Guidelines
BOD	Biochemical Oxygen Demand
CA	Cluster Analysis
CCREM	Canadian Council of Resource and Environment Ministers
Chl *a*	Chlorophyll *a*
COD	Chemical Oxygen Demand
CWQG	Canadian Water Quality Guidelines
DN	Dissolved Nitrogen
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DP	Dissolved Phosphorus
EQMB	Environmental Quality Monitoring Branch
JTU	Jackson Turbidity Units
O&G	Oil and Grease
PCA	Principal Component Analysis
PN	Particulate Nitrogen
POC	Particulate Organic Carbon
PPWB	Prairie Provinces Water Board
PPWBO	Prairie Provinces Water Board Objectives
RCU	Relative Colour Units
SS	Suspended Solids
T&L	Tannin and Lignin
TDP	Total Dissolved Phosphorus
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus

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1.0 INTRODUCTION

The Battle River is a tributary of the North Saskatchewan River, which is a major tributary of the Saskatchewan-Nelson River system. The Battle River takes its source in Battle Lake, east of the foothills, and flows eastward across central Alberta and into Saskatchewan where it joins the North Saskatchewan River near the towns of North and South Battleford.

The seasonal nature of flow in the Battle River was recognized as a major obstacle to meet the projected increases in water demand for municipal, agricultural, and especially industrial uses at an early stage in the basin's resource planning studies (Planning Division 1981). Several options such as the enhancement or creation of additional on-stream or off-stream storage reservoirs and the diversion of water from the North Saskatchewan River have been considered to ensure that water demands are met.

As water quality is usually intimately linked to water quantity, most water quality studies on the Battle River have been conducted to provide background information so that water quality changes resulting from proposed scenarios for flow augmentation could be predicted. All of these water quality studies have focused on the Battle River between Ponoka and the Alberta-Saskatchewan border.

Grant and Bramm (1979) conducted the first, comprehensive water quality overview of the Battle River in 1977-1978. Another series of general water quality surveys were conducted from 1984 to 1986 mainly to refine models describing the predicted effects of a proposed water diversion from the North Saskatchewan River on Battle River water quality (Corkum 1984, Nanuk Engineering 1985, Water Quality Monitoring Branch 1985).

Fernet et al. (1985) conducted a detailed fish habitat study of the Battle River and considered the implications of flow augmentation on the river's fisheries. Experimental attempts to enhance winter dissolved oxygen levels by augmenting river flows through scheduled releases from Pigeon and Coal lakes are documented in Sloman (1984).

In 1989 the former Environmental Quality Monitoring Branch (EQMB) undertook an extensive monitoring program on the Battle River. One study component was to conduct a pilot study designed to assess and compare the suitability of water and other media such as bottom sediments, suspended solids and biota for monitoring trace metals and pesticides. Results of that study are presented in Anderson et al. (1992). The other study component consisted of a series of synoptic water quality surveys of the Battle River and its tributaries. Data collected during these surveys are presented and evaluated in this report. The principal objectives of this report are:

- to provide a spatial and temporal characterization of present water quality conditions of the Battle River over its entire length and of its tributaries;

- to evaluate long-term trends in the water quality of the Battle River at Unwin;
- to assess factors which affect the general water quality of the river such as point sources (tributaries, effluents) and non-point sources (diffuse runoff, groundwater);
- to evaluate the short-term, local effects on water quality of spring and fall municipal discharges;
- to compare present and historical water quality data with published objectives or guidelines;
- to document spatial and temporal trends in aquatic invertebrate community composition and to relate these to trends observed in physical, chemical, or other biological river characteristics.

2.0 METHODS

2.1 DATA COLLECTION

2.1.1 Synoptic Survey

The synoptic surveys were designed to characterize longitudinal and seasonal changes in specific physical, chemical, and biological variables, to characterize the influence of point and non-point sources, and to describe the effects of on-stream lakes on the river's water quality.

Thirteen synoptic surveys were carried out on the Battle River and its tributaries during 1989 and 1990. Seven surveys were conducted at monthly intervals from May 1989 to October 1989 at 15 mainstem sites (Table 1, Figure 1). Two surveys were carried out in the winter: one in January 1990 at all mainstem sites; a second in February 1990 at six of the mainstem sites (Table 1). In 1990 four surveys were conducted at the mainstem sites and on 14 tributaries near their confluence with the Battle River (Table 1, Figure 1). Tributaries, which receive municipal or industrial (coal mine), effluent were sampled for the same variables as the mainstem sites. Remaining tributaries were sampled for all of these variables once in May 1990, whereas only field measurements of temperature, dissolved oxygen, pH and conductivity were taken during the three other surveys (Table 1).

Field measurements of pH, dissolved oxygen, conductivity, and temperature were taken at each site and on each sampling occasion with a Hydrolab 4000 Model 4041. Discrete samples for chemical analysis were taken from the center of the river channel. When wading to the sampling point was not practical, samples were collected from bridge decks.

Samples were preserved as required at the end of their collection day, and kept dark and cool until they were analyzed. Samples for analysis of planktonic chlorophyll *a* and the dissolved fractions of phosphorus, nitrogen, and metals were filtered at the end of their collection day. Samples normally reached the analytical laboratories the morning after they were collected.

Table 1. List of sites sampled in the Battle River and its tributaries in 1989 and 1990.

NUMBER, NAME AND LOCATION		NAQUADAT CODE	DISTANCE (km) FROM		SAMPLING SCHEDULE
			SOURCE	CONFLUENCE WITH NSR	
Site 1	Battle River at Highway 611 (West of Usona)	00AL05FA0250	49	986	● ○ ■
	Pigeon Lake Creek	00AL05FA0225	53	982	□
Site 2	Battle River at Highway 53	00AL05FA0280	89	946	● ○ ■
	Wolf Creek Near Highway 2	00AL05FA287	96	939	■
Site 3	Battle River Near Highway 2A (d/s Ponoka)	00AL05FA0413	124	911	● ■
Site 4	Battle River at Highway 611 (d/s Samson Lake)	00AL05FA0500	200	835	● ■
	Pipestone Creek at Highway 822	00AL05FA0600	227	808	■
Site 5	Battle River at Highway 21	00AL05FA0700	258	777	● ■
	Camrose Creek near Mouth	00AL05FA0745	269	766	■
Site 6	Battle River d/s of Camrose Creek	00AL05FA0750	273	762	● ○ ■
Site 7	Battle River at Highway 850 (d/s Driedmeat Creek)	00AL05FA1000	377	718	● ■
	Meeting Creek Near Mouth	00AL05FC0290	367	668	■
	Bigknife Creek at Bigknife Provincial Park	00AL05FC0400	395	640	□
Site 8	Battle River at Bigknife Provincial Park	00AL05FC0660	398	637	● ■
Site 9	Battle River at Highway 861 (d/s Forestburg Res.)	00AL05FC0680	435	600	● ■
	Paintearth Creek	00AL05FC0690	455	580	■
	Castor Creek	00AL05FC0800	484	551	■
Site 10	Battle River at Highway 872	00AL05FC1000	518	517	● ○ ■
Site 11	Battle River d/s Hardisty	00AL05FB0500	612	423	● ■
	Iron Creek at Highway 881	00AL05FB0700	614	421	■
	Battle River d/s Iron Creek	00AL05FB1000	618	417	■
	Grattan Creek	00AL05FE0175	655	380	□
Site 12	Battle River at Highway 41	00AL05FE0400	687	348	● ■
	Buffalo Creek at Highway 41	00AL05FE0500	687	348	□
	Grizzly Bear Creek	00AL05FE0600	710	325	□
Site 13	Battle River at Highway 897	00AL05FE0850	760	275	● ■
	Ribstone Creek at Highway 14	00AL05FE0875	796	239	■
	Blackfoot Creek at Unwin Road	00AL05FE0890	811	224	□
Site 14	Battle River near Unwin	00SA05FE1000	826	209	● ○ ■
Site 15	Battle River near Mouth (u/s Battlefords)	00SA05FF1000	1020	5	● ○ ■

Sampling Schedule

● Sampled in each survey of 1989 and 1990
○ Sampled in February 1990
■ Sampled in four surveys of 1990
□ Sampled in May 1990, only

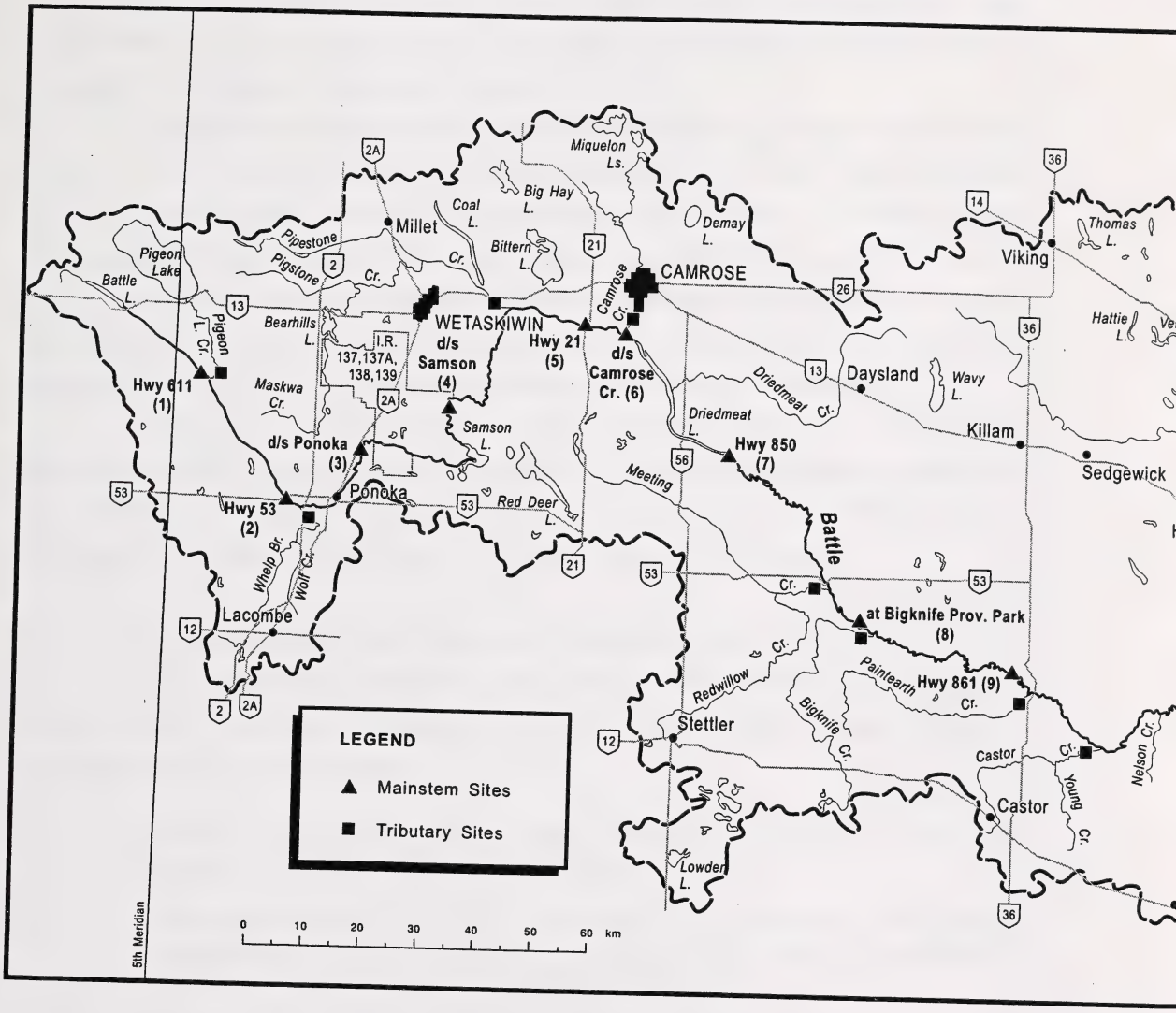
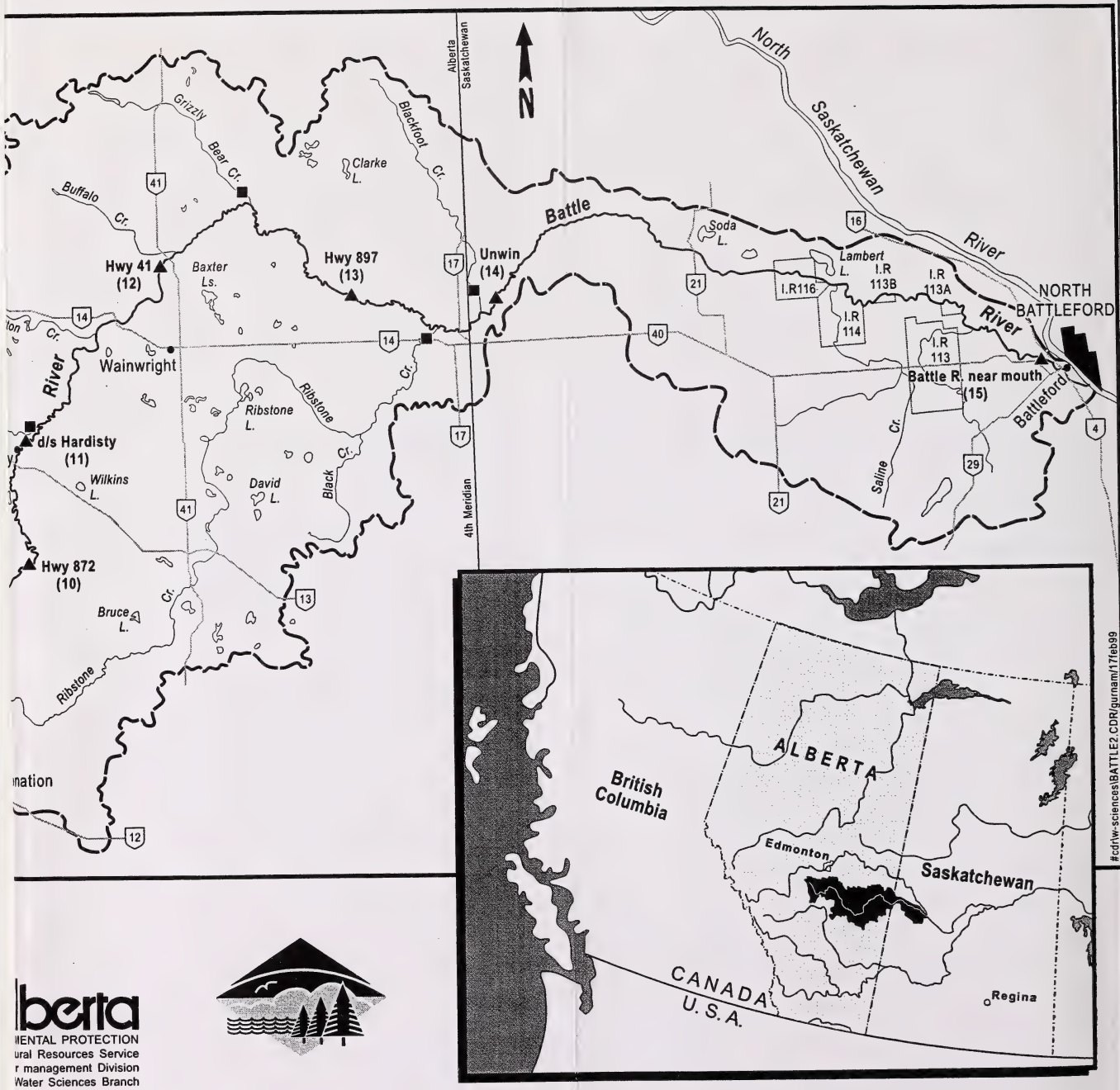


Figure 1. Map of the Battle River Basin showing mainstem and tributary sites sampled in 1989 and 1990

ENV



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r management Division
Water Sciences Branch

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Replicate and field blank samples were collected periodically for quality assurance. The replicate consisted of two serial grab samples collected a few minutes apart at the same site. For blank samples, distilled water from the analytical laboratory was taken into the field and used to fill regular sample bottles under typical sampling conditions. The replicate and field blanks were submitted "blind" to the laboratory. These data are summarized in Appendix 6.

A complete list of water quality variables for which samples were collected at each site is given in Table 2. Analytical methods used for the surveys conducted in 1989 and 1990 are outlined in Environment Canada (1988). Most water quality variables were analyzed at the Water Analysis Laboratory (Alberta Environmental Center or AEC, Vegreville); chlorophyll *a* samples were analyzed at the Millwoods facility of the MB, Edmonton; bacteriological samples were analyzed by the Alberta Provincial Laboratory, Edmonton; trace organic compounds were analyzed at the Research and Methods Development Branch (AEC, Vegreville). Results of survey data are presented in Appendix 1.

Discharge was measured at all sampling sites along the Battle River or its tributaries by the MB (AEP) or by Water Survey of Canada (WSC) on the day of water quality sampling. Discharge was measured only once (May 1990) in tributaries which do not receive wastewater or industrial discharges. A list of hydrometric stations is given in Table 3. Flow data are summarized in Appendix 2.

2.1.2 Survey of Battle River During Discharge of Ponoka Wastewater

Most municipalities in the Battle River basin discharge their wastewater indirectly to the Battle River via ditches or into tributaries which flow to the river. There are a series of logistic problems in sampling the plumes in the Battle River:

1. travel time in these creeks or ditches is difficult to determine because flow is often impeded temporarily (i.e., log jams, beaver dams, weed growth);

2. travel distance is generally quite long. Chemical and biological assimilation and degradation processes which occur along the ditches or creeks are likely to alter the concentration of substances in the plume during its movement to the Battle River;

3. although most municipalities discharge in spring and fall, the entire discharge period in spring or fall can be spread over up to four months. Figure 2 compares the discharge time of municipalities to the Battle River basin with the timing of synoptic surveys;

4. some municipalities do not decide on the exact date of discharge more than two weeks in advance.

Table 2. Summary of water quality variables monitored as part of synoptic water quality surveys conducted in the Battle River (units in mg/L unless otherwise stated).

VARIABLE			NAQUADAT CODE	DETECTION LIMIT (in mg/L)
Water Temperature (°C)		*	02061 F	0.1
pH (pH units)		*	10301 F	0.1
Specific Conductance (µS/cm)		*	02041 L	1.0
Dissolved Oxygen		*	08102 F and 08101 L	0.1
Residue Nonfilterable		*	10401 L	-
Residue Filterable		*	10451 L	-
Turbidity (NTU)		*	02074 L	-
Alkalinity Total		*	10101 L	-
Hardness Total		*	10605 L	-
Total Dissolved Solids		*	00205 L	-
Calcium		*	20107 L	1.0
Magnesium		*	12105 L	0.1
Sodium		*	11103 L	0.1
Potassium		*	19103 L	0.1
Bicarbonate		*	06202 L	-
Carbonate		*	06302 L	1.0
Chloride		*	17203 L	0.1
Sulphate		*	16306 L	1.0
Fluoride		*	09107 L	0.1
Silica Reactive		*	14107 L	0.1
Biochemical Oxygen Demand		*	08202 L	0.2
Chemical Oxygen Demand		*	08304 L	10.0
True Colour (RCU)		*	02024 L	-
Tannin and Lignin		-	06551 L	0.1
Oil and Grease		-	06524 L or 06521 L	1.0 or 0.1
Phenolic Material		-	06537 L	0.001
Carbon Dissolved Organic		*	06107 L	0.4
Carbon Particulate		*	06905 L	0.02
Phosphorus Particulate		*	15901 L	-
Phosphorus Total		*	15421 L	0.006
Nitrogen Dissolved Ammonia		*	07562 L	0.001
Nitrogen Dissolved NO_3^-+NO_2^-		*	07105 L	0.01
Nitrogen Dissolved NO_2^-		*	07205 L	0.001
Nitrogen Dissolved Kjeldahl		*	07017 L	-
Nitrogen Total Particulate Kjeldahl		*	07920 L	-
Nitrogen Total Kjeldahl		*	07021 L	-
Nitrogen Total Particulate		*	07906 L	-
Nitrogen Total Calculated		*	07602 L	-
Chlorophyll a (mg/m^3)		*	06715 L	0.1
Coliforms Total (# per 100 mL)		*	36001 L	1.0
Coliforms Fecal (# per 100 mL)		*	36011 L	4.0
Aluminum	- Extractable	*	13030 L	0.002
	- Dissolved	-	13109 L	0.002
Arsenic	- Total	*	33005 L	0.0002
	- Dissolved	-	33102 L	0.0002
Barium	- Total	*	56009 L	0.001
	- Dissolved	-	56109 L	0.001
Beryllium	- Dissolved	-	04103 L	0.001
Cadmium	- Total	*	48009 L	0.001
	- Dissolved	-	48109 L	0.001
Cobalt	- Total	*	27009 L	0.001
	- Dissolved	-	27109 L	0.001
				0.001
Chromium	- Total	*	24009 L	0.001
	- Dissolved	-	24109 L	

VARIABLE			NAQUADAT CODE	DETECTION LIMIT (in mg/L)
Copper	- Total	*	29009 L	0.001
	- Dissolved	-	29109 L	0.001
Lead	- Total	*	82301 L	0.002
	- Dissolved	-	82103 L	0.002
Mercury	- Total	*	80015 L	0.0001
Molybdenum	- Total	*	42009 L	0.001
	- Dissolved	-	42109 L	0.001
Manganese	- Total	*	25004 L	0.001
	- Dissolved	-	25109 L	0.001
Nickel	- Total	*	28009 L	0.001
	- Dissolved	-	28109 L	0.001
Iron	- Total	*	26009 L	0.001
	- Dissolved	-	26109 L	0.001
Zinc	- Total	*	30009 L	0.001
	- Dissolved	-	30109 L	0.001
Vanadium	- Total	*	23009 L	0.002
	- Dissolved	-	23109 L	0.002
Selenium	- Total	*	34005 L	0.0001
	- Dissolved	-	34102 L	0.0001
LONG-TERM RIVER NETWORK PESTICIDE SCAN (DETECTION LIMIT IN µg/L)				
alpha-Chlordane			93001	0.02
gamma-Chlordane			93002	0.005
p,p'-DDD			93006	0.01
p,p'-DDE			93008	0.01
o,p'-DDT			93009	0.02
p,p'-DDT			93010	0.02
Dieldrin			93012	0.01
alpha-Endosulfan			93014	0.01
beta-Endosulfan			93015	0.01
Endrin			93016	0.01
Heptachlor			93017	0.01
Heptachlor Epoxide			93018	0.01
Hexachlorobenzene			93019	0.005
alpha-BHC			93020	0.01
gamma-BHC			93022	0.01
p,p'-Methoxychlor			93024	0.03
Diazinon			94026	0.5
Mirex			93025	0.02
2,4-D			93037	0.2
2,4,5-T			93038	0.2
2,4-DB			93043	0.3
2,4-DP			93044	0.2
Disyston			94007	25.0
Ethion			94008	0.05
Guthion			94012	2.0
Malathion			94013	0.17
Methyl Parathion			94014	0.05
Parathion			94019	0.06
Phorate			94020	0.20
Ronnel			94021	0.1
Aldrin				0.01
MCPA				0.2
PCB's				0.05
SEMI VOLATIVE COMPOUNDS				
Benzoic Acid			95000	2.0
4-Chloro-3-Methylphenol			95001	1.0
2-Chlorophenol			95002	2.0
2,4-Dichlorophenol			95003	1.0

VARIABLE	NAQUADAT CODE	DETECTION LIMIT (in mg/L)
2,4-Dimethyl Phenol	95004	2.0
2-Methyl-4,6-Dinitrophenol	95005	1.0
2,4-Dinitrophenol	95006	1.0
Hexadecanoic Acid	95007	3.0
2-Nitrophenol	95008	1.0
4-Nitrophenol	95009	1.0
Pentachlorophenol	95010	1.0
Phenol	95011	1.0
2,4,5-Trichlorophenol	95012	1.0
2,4,6-Trichlorophenol	95013	1.0
Acenaphthene	95014	1.0
Acenaphthylene	95015	1.0
Anthracene	95016	1.0
Benzo(a)Anthracene	95017	1.0
Benzo(k)Fluoranthene	95018	1.0
Benzo(ghi)Perylene	95019	2.0
Benzo(a)Pyrene	95020	1.0
Chrysene	95021	1.0
Dibenzo(ah)Anthracene	95022	5.0
Fluoranthene	95023	1.0
Fluorene	95024	1.0
Indeno(1,2,30-cd)Pyrene	95025	1.0
Naphthalene	95026	1.0
Perylene	95027	1.0
Phenanthrene	95028	1.0
Pyrene	95029	1.0
Benzo(b)Fluoranthene	95031	1.0
2-Chloronaphthalene	95032	1.0
Hexachlorobenzene	95033	1.0
Hexachlorobutadiene	95034	5.0
Hexachlorocyclopentadiene	95035	1.0
Hexachloroethane	95036	5.0
1,2,4-Trichlorobenzene	95037	1.0
Isophorone	95030	1.0
Benzidine	95038	2.0
2,4-Dinitrotoluene	95039	1.0
2,6-Dinitrotoluene	95040	1.0
1,2-Diphenylhydrazine	95041	1.0
Nitrobenzene	95042	1.0
N-Nitrosodiphenylamine	95043	1.0
N-Nitroso-DI-n-Propylamine	95044	2.0
4-Bromophenyl Phenyl Ether	95045	1.0
Bis(2-Chloroethoxy)Methane	95046	1.0
Bis(2-Chloroethyl)Ether	95047	1.0
Bis(2-Chloroisopropyl)Ether	95048	1.0
4-Chlorophenyl Phenyl Ether	95049	1.0
Butylbenzylphthalate	95050	1.0
Dibutylphthalate	95051	1.0
Diethylphthalate	95052	1.0
Dimethylphthalate	95053	1.0
Di-n-Octylphthalate	95054	1.0
Bis(2-Ethylhexyl)Phthalate	95055	1.0

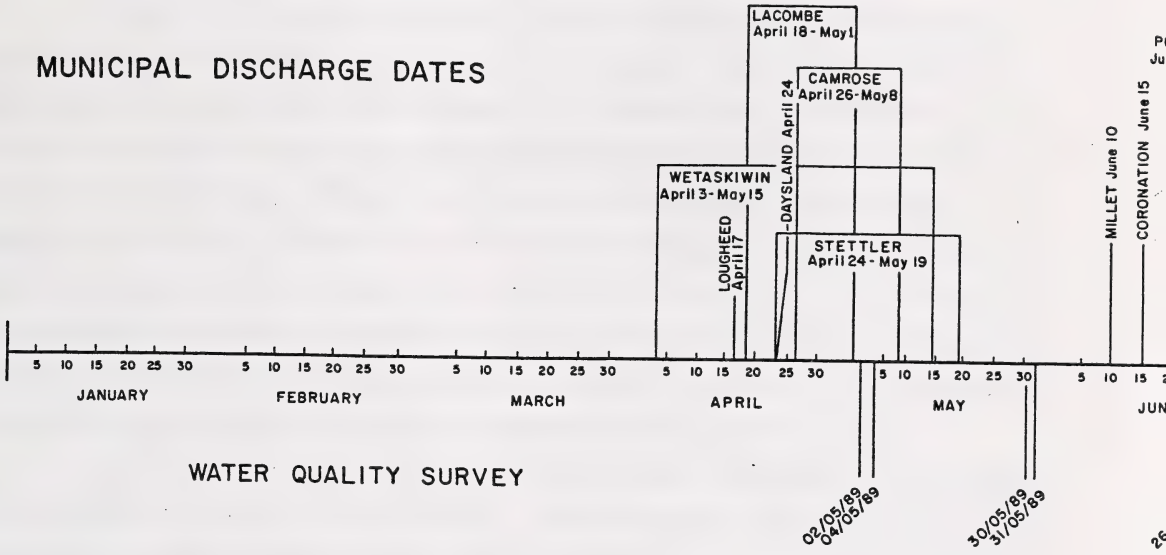
MDL = method detection limit
Variables marked with an asterix were monitored during discharge of Ponoka Wastewater

Table 3. Hydrometric stations monitored in the Battle River during 1989 and 1990.

BATTLE RIVER		
At Highway 611 (West of Usona)	05FA923	
At Highway 53	05FA926	
At Ponoka	05FA001	(x)
At Highway 611 (d/s Samson Lake)	05FA919	
At Highway 21	05FA924	
At Highway 850	05FA925	
Near Forestburg	05FC001	(x)
At Highway 861	05FC905	
At Highway 872	05FC906	
Near Hardisty	05FB903	
At Highway 897	05FE906	
Near Saskatchewan Boundary	05FE004	(x)
At Battleford	05FF001	(x)
TRIBUTARIES		
Pigeon Lake Creek		(x)
Wolf Creek	05FA913	
Pipestone Creek	05FA920	
Camrose Creek	05FA921	
Meeting Creek at Mouth	05FC910	
Meeting Creek near Donalda	05FC006	(x)
Meeting Creek near Red Willow	05FC005	(x)
Bigknife Creek	05FC907	
Paintearth Creek	05FC908	
Castor Creek	05FC909	
Iron Creek		
Grattan Creek	05FB904	
Buffalo Creek	05FE002	(x)
Grizzly Bear Creek	05FE907	
Ribstone Creek	05FD905	
Blackfoot Creek	05FE908	

"x" Indicates Water Survey Canada, all other stations monitored by Survey Branch, Alberta Environment

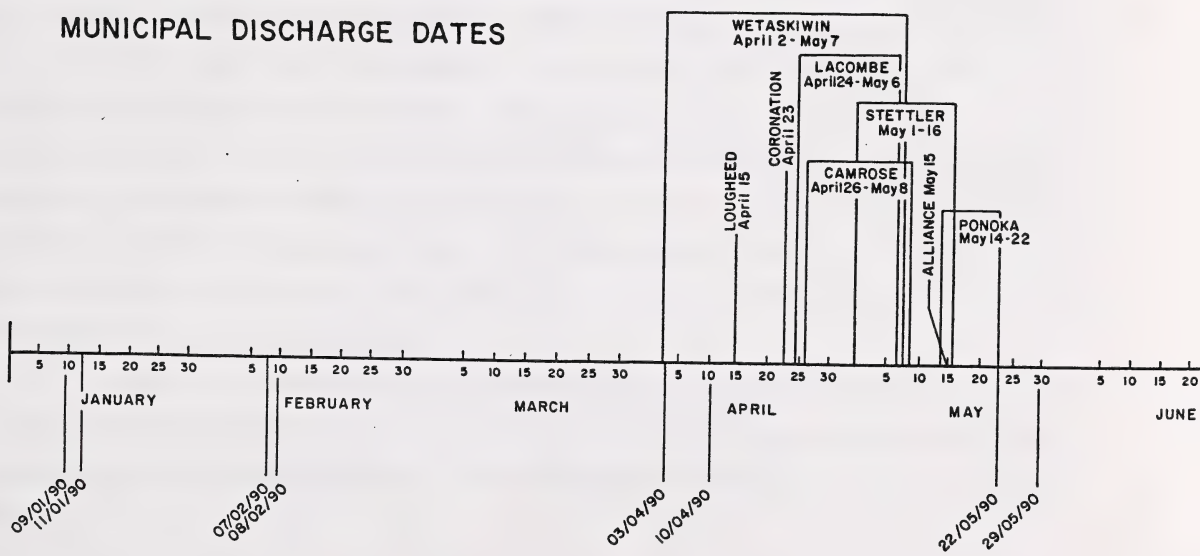
MUNICIPAL DISCHARGE DATES



WATER QUALITY SURVEY

02/05/89
04/05/89
30/05/89
31/05/89

MUNICIPAL DISCHARGE DATES



09/01/90
11/01/90
07/02/90
08/02/90
03/04/90
10/04/90
22/05/90
29/05/90

WATER QUALITY SURVEYS

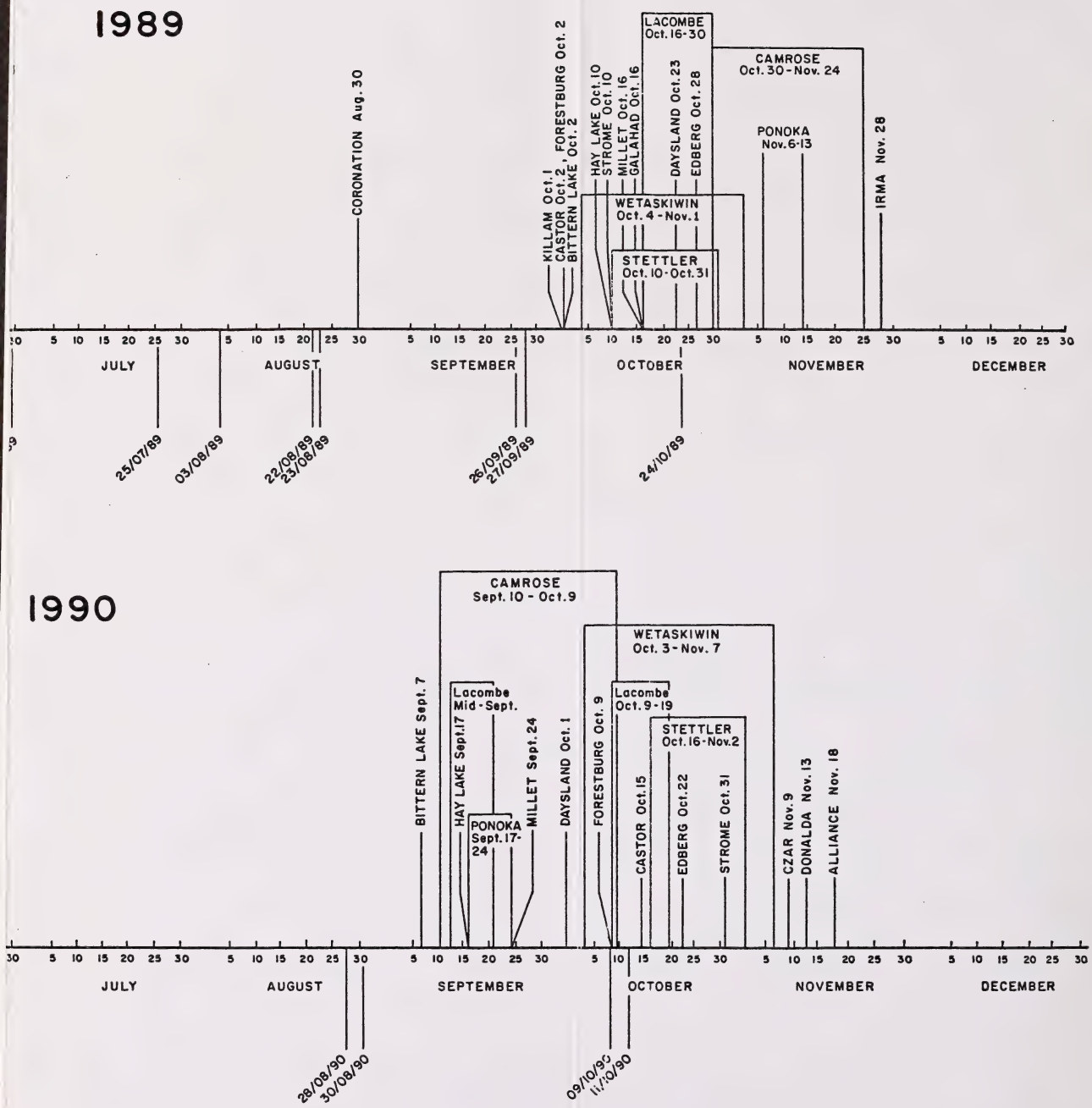


FIGURE 2. MUNICIPAL EFFLUENT DISCHARGE DATES AND DATES OF WATER QUALITY SURVEYS IN BATTLE RIVER IN 1989 AND 1990.

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Ponoka was the only municipality with more than 5000 inhabitants which discharged its wastewater directly to the river (i.e., not via a ditch or creek). The river flows unimpeded for approximately 10 km downstream of the discharge point into Samson Lake. For these reasons, Ponoka was chosen as the subject of a case study which was to reflect the short-term and local effect of municipal discharges on the Battle River. Changes in water quality were characterized during the spring and fall discharges. The hospital in Ponoka had its own treatment system and discharged its wastewater continuously to the Battle River at a rate of 300 to 400 m^3/day (i.e., 0.005 m^3/s). It is important to note that sampling sites downstream of Ponoka reflect the influence of the intermittent discharges from the town as well as that from the continuous discharges from the hospital. The hospital stopped chlorinating its effluent in the summer of 1989 (A. Kennedy, Environmental Sciences Division, pers. comm.).

Samples were collected from three sites on the Battle River: 3 km upstream of the municipal outfall (at Highway 2A, station 00AL05FA0300); 4 km downstream (at Diamond #5 road, station 00AL05FA0412), and 8 km downstream of the outfall (near Highway 2A, station 00AL05FA0413). As the quality of the effluent tends to vary over time during the discharge period, time-integrated samples were collected from these three sites during the entire discharge period (nine and eight days in spring and fall, respectively). Each sample consisted of 24 samples collected at hourly intervals from the center of the river by an automatic sampler (ISCO model 2070/2100). ISCO sampling started approximately 24 hours prior to the scheduled release start and continued at least 24 hours after conductivity readings (Field measurements with Hydrolab 4000 model 4041) indicated that the effluent plume had traveled downstream of the sampling points. In spring, effluent was released earlier than scheduled and the first ISCO samples were taken from the plume. Samples were retrieved every 24 hours. At that time Hydrolab readings of conductivity, pH, DO, and temperature were made and grab samples for total and fecal coliform bacteria were taken from the center channel. Water quality data taken from the Battle River during the Ponoka wastewater survey are presented in Appendix 3.

Datasondes (Datasonde 1 model number 2030) installed at the three sampling sites recorded temperature, pH, dissolved oxygen, and conductivity hourly. A list of water quality variables sampled during these surveys is shown in Table 2. Analytical methods are described in Environment Canada (1988).

2.1.3 Diurnal Cycles

Diurnal fluctuations in dissolved oxygen, pH, temperature and conductivity were recorded with Datasondes (Datasonde 1, model number 2030) for approximately one week in summer 1989 and winter 1989-1990 at three sites in the Battle River (i.e., Highway 611, downstream Camrose Creek, Unwin).

2.1.4 Aquatic Invertebrates Surveys

Benthic invertebrates were sampled quantitatively at mainstem sites in spring and fall of 1989. Samples were taken from the center of the channel with an Ekman Dredge; each sample consisted of 5 replicates which were sieved in the field (mesh size 250 µm) and preserved immediately thereafter in 4% formaldehyde. Spring samples were collected with a 15.5 by 15.5 cm Ekman Dredge; a larger model (22.5 by 22.5 cm) was used in fall.

Invertebrates were also sampled qualitatively along the shoreline during the fall survey. These samples were collected from areas with and without macrophyte growth by sweeping a large dip net near the river's bottom. The purpose of these samples was merely to document the difference in species diversity between the center channel and the shoreline.

Zoobenthic samples were stained with Rose Bengal upon return to the laboratory (Mason and Yevich 1967). Samples were sorted through two sieves with mesh apertures of 2 and 0.213 mm. Coarse fractions (residue of 2 mm screen) and fine fractions (residue on 0.213 mm screen) of each sample were sorted under a dissecting microscope (magnification range 6 to 50X). It was necessary to sub-sample the fine fraction of some samples that contained large numbers of organisms. Sub-sampling was performed using the Imhoff cone method described by Wrona et al. (1982). Specimens were counted and identified according to Baumann et al. (1977), Edmunds et al. (1976), Merritt and Cummins (1984), Pennak (1978), and Wiggins (1977).

Aquatic invertebrate data are shown in Appendix 4.

2.1.5 Long-Term Data

The Battle River has been monitored monthly at Unwin (Saskatchewan) for a wide range of water quality variables since 1974 by Environment Canada on behalf of the Prairie Provinces Water Board (PPWB). The data base was retrieved from the federal NAQUADAT data storage and retrieval system and the information was used to characterize long-term and seasonal trends in river water quality at that site. Analytical methods are described in Environment Canada (1988) and relevant data are summarized in Appendix 5.

2.2 DATA ANALYSIS

2.2.1 Water Quality Data

2.2.1.1 Long-Term Data

The long-term data set at Unwin was used to determine whether water quality variables changed seasonally, according to flow, or over the period of record. Seasonal patterns were explored by visual examination of monthly or quarterly Box and Whisker plots. These plots represent medians (central, horizontal bar), interquartiles (Box) and extremes (Whiskers). Since river flow can influence concentrations of many water quality variables, regression analysis was performed on the data to determine which variables were flow dependent. If the correlation coefficient was significant and, if flow explained 40% or more of the sample variance, the variable was considered to be flow dependent. Residuals (i.e., portion of the variance not explained by the relationship with flow) of the best fitting regression model were retained for further analysis.

Correlograms were used to check raw data or flow adjusted (residuals) data for serial correlation. Serial correlation occurs in a data set when a data point is influenced by the value of the preceding data point and when it influences the value of the following data point. According to J.C. Loftis (pers. comm., Colorado State University, June 1991), serial correlation can affect the outcome of trend analysis by increasing the probability of Type II errors (i.e., erroneously recognizing the existence of a trend). Consequently serial correlation makes the result of trend analysis questionable only when a significant trend is identified. Serial correlation can be reduced or eliminated by using quarterly rather than monthly data. The Kendall test (no seasonality) or, seasonal Kendall (seasonality present) was used to determine the statistical significance of monotonic trends and to estimate the magnitude of these trends. The test was performed on raw data (flow independent variable), flow adjusted data (flow dependent variable) and monthly or quarterly data depending on the presence of serial correlation. Analyses of long-term data were performed on an IBM-PC personal computer using Trend (Shaw 1990). Trend is a menu-driven, integrated computer procedure for evaluating water quality time series data. The driving components include a Lotus 123 program (Flow) to assess flow-dependency of river water quality and a PASCAL program (WQSTAT II) to test time-series data for long-term trends (Phillips et al. 1988). Concentrations below the analytical detection limit were replaced by values half the detection limit for the analysis of long-term data. Trend analysis was not performed on variables for which 50% or more records were below the method detection limit.

2.2.1.2 Survey Data

Survey data from 1989-1990 are mostly summarized in graphical form. Average water quality conditions at survey sites are represented by arithmetic means for all surveys, extreme conditions are reflected in the minima and maxima recorded during the surveys. In some instances data have been plotted for individual surveys to illustrate changes in water quality induced by discontinuous (passage of effluent plume), or seasonal events.

Differences in water quality conditions upstream and downstream of the Ponoka wastewater discharge point are illustrated in time-series plots of relevant variables.

Mass transport or mass load was calculated by multiplying concentrations (C) with average daily river discharge values (Q). Mass loads were determined for all mainstem sites sampled from May 1989 to April 1990, but excluding winter surveys for which no flow data were available. Mass loads were also determined for mainstem and tributary sites sampled during the four surveys conducted in 1990. The federal data base at Unwin was used to estimate the total annual mass load of selected variables. Annual mass loads were obtained from:

$$\sum_{i=1}^{12} \bar{\varphi}_i \bullet C_i \bullet d_i$$

where: φ_i is average daily discharge in month i
C_i is concentration recorded in month i
d_i number of days in month i

Concentrations below the analytical detection limit were set to zero for the calculation of mass loads.

Analyses of survey data were performed on a Wang and an IBM-PC personal computer using Lotus 123 and Freelance software.

Two multivariate techniques, Cluster analysis (CA) and principal components analysis (PCA) were used in the analysis of aquatic invertebrate data. Both CA and PCA provide a means of comparing samples (or sites) using data from several variables (invertebrate counts) at once.

Cluster analysis is a technique whereby samples are grouped according to similarities among variables. The similarity index used in the present analysis is the Squared Euelidean Distance and the Ward (1963) method was used for the fusion of similar clusters. Results are presented graphically. Samples with similar characteristics cluster together, and the difference in similarity coefficient between clusters or their fusion points can be used as a relative measure of the degree of similarity (or dissimilarity) between clusters.

Principal components analysis involves transforming a set of variables to a new set of variables (principal components) that account for the largest possible amount of variation in the data (Green 1979). Eigen vector values provide, for each component, a measure of the importance of each variable. Therefore, variables with high positive or negative eigen vector values can be used to characterize each component. Variables which typify a sample or a cluster of samples can be derived from the position of this sample or sample cluster on the ordination graph.

The SPSSx statistical package was used for data file manipulation (SPSS Inc. 1983), and the multivariate analyses were performed using CLUSTAN (Wishart 1987) on an Amdahl 5870 computer.

2.2.1.3 Comparison of Battle River Data With Surface Water Quality Objectives or Guidelines

River water quality was assessed by comparing longitudinal survey data and long-term data at Unwin with Alberta Ambient Surface Water Quality Interim Guidelines (AASWQIG, Alberta Environment 1993), Canadian Water Quality Guidelines (CWQG, CCREM 1987) and Prairie Provinces Water Quality Objectives (PPWQO) for the Battle River (Prairie Provinces Water Board (PPWB 1990). If there were different guidelines or objectives for the protection of various uses, the most restrictive ones were chosen. Usually these were for the protection of aquatic life. However, when appropriate, guidelines for agricultural or recreational uses of water were also considered since these are other important uses in the basin.

When Battle River data fell outside of the range of recommended values for the respective user they were qualified as non-compliant.

3.0 BASIN CHARACTERISTICS

3.1 ECOREGION AND CLIMATE

The Battle River flows through two main ecoregions (Strong and Leggat 1981). Battle Lake and the first 10 to 20 kilometres of the river are located in the boreal mixed wood biome which is typified by aspen poplar, gray luvisol soils and a boreal climate. The remainder of the basin lies in the aspen parkland biome which is typified by aspen and rough fescue grassland, grey and black chernozem soils and a prairie boreal climate.

Mean annual precipitation is somewhat lower and mean summer temperature somewhat higher in the aspen parkland biome than in the boreal mixed wood biome. Figliuzzi (1978) reports mean annual precipitation of 500 mm in the west to 350 mm in the eastern portion of the basin and mean annual evaporation ranging from 635 mm in the west to 800 mm in the south eastern regions.

From a comparison of precipitation records for the period 1914-1930 and 1967-1976, Stolte and Herrington (1980) concluded that mean monthly precipitation had not changed significantly at Lacombe and Wetaskiwin. However, summer storms had become more frequent and somewhat longer in duration, but less intense (yielding less precipitation). A slight trend towards higher precipitation was noted for the winter period at the Battlefords (Saskatchewan). Stolte and Herrington also showed that the mean growing season temperature was higher at Lacombe and Wetaskiwin for the 1967-1974 period than for the 1920-1930 period.

Total annual precipitation at Camrose was 477.8 mm in 1989 and 489.4 mm in 1990 (data from Water Sciences Branch, AEP and Environment Canada, Atmospheric Environmental Service) which is slightly above the normal annual average of 453.2 mm (Environment Canada 1982). Compared to monthly averages, monthly precipitation records at several sites in the basin varied rather inconsistently during 1989 and 1990. Records suggest a slightly higher incidence of below average precipitation for the eastern portion of the basin. Heavy rainstorms occurred in late June and July 1990 in the upper portion of the basin and resulted in mean monthly precipitation records that were more than twice the average at Camrose. These rainstorms decreased in intensity in an eastward direction, as illustrated by the lower precipitation at Wainwright and Coronation during July (Table 4). On July 2 and 3, 1990, a heavy rainstorm occurred immediately east of the Battle River between Ponoka and Wetaskiwin; the rainfall exceeded the 1 in 100 year, 24 hour precipitation value of 110 mm (preliminary estimates, Hydrology Section, Water Sciences Branch). The increase in river discharge at Ponoka following the July 2nd and 3rd 1990 rainstorm in that area exceeded the return period of 1 in 100 year (preliminary estimates, Hydrology Section, Water Sciences Branch).

3.2 GEOLOGY

3.2.1 Bedrock Geology

Maps presented in the Atlas of Alberta (1969), Allan and Rutherford (1934), Le Breton (1971), and Green (1972), indicate that bedrock geology in the Battle River basin is dominated by Tertiary and Upper Cretaceous Formations. Battle Lake and the Battle River as far as the Ponoka area rests on sandstones and shale from the Paskapoo formation (Tertiary) whereas bedrock between the Ponoka and the Forestburg area consists of brackish and freshwater deposits consisting of shale, sandstone, bentonite and coal seams from the Edmonton formation (upper Cretaceous). A relatively narrow strip of bedrock from the Bearpaw Formation (upper Cretaceous) extends in a northwest/southeast direction between the Forestburg and Hardisty area and consists of marine shale and fine-grained sandstone. Bedrock in the

Table 4. Monthly precipitation records (precipitation in mm).

LOCATION	MONTH											
	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
CAMROSE (1)												
Avg (1955-1985)	27.0	19.1	19.7	19.6	46.0	79.6	74.1	74.4	39.7	15.4	16.6	21.8
1989	39.0	8.4	13.0	30.4	58.0	54.6	84.2	73.8	25.2	29.4	30.0	31.8
1990	24.6	27.2	13.6	NA	36.6	78.0	157.4	59.8	5.6	26.6	NA	NA
WAINWRIGHT (2)												
Avg (1981-1985)	15.7	12.2	33.7	24.5	37.7	74.9	60.8	62.2	52.2	19.1	15.8	21.9
1989	37.3	7.0	5.5	6.9	NA	56.8	49.5	NA	NA	16.6	19.3	29.5
1990	19.6	21.8	17.8	NA	6.6	99.4	115.0	NA	NA	NA	NA	NA
CORONATION (1)												
Avg (1955-1985)	22.0	16.0	18.0	22.0	37.0	60.0	66.0	46.0	37.0	15.0	37.0	15.0
1989	22.0	7.0	8.0	11.0	39.0	78.0	49.0	74.0	21.0	13.0	18.0	20.0
1990	17.0	17.0	26.0	21.0	36.0	82.0	89.0	32.0	5.0	8.0	16.6	17.0

(1) Source: Water Resources Management Services, Alberta Environment

(2) Source: Atmospheric Environment Services, Environment Canada

NA = Not available

remaining part of the basin consists of fresh to brackish water shale, and sandstone deposits of the Belly River Formation (upper Cretaceous).

Coal seams of commercial thickness occur in the lower part of the Edmonton formation. Thinner coal seams also occur in the other two upper cretaceous formations of the Battle River basin (e.g., Maslowski-Schutze et al. 1986).

3.2.2 Surficial Geology

Most of the bedrock in the area is overlain by surficial deposits commonly comprising till (an unsorted and unstratified glacially derived mixture of clay, silt, sand, pebbles, and boulders), lacustrine clay, sand and gravel, and wind blown sand deposits (Le Breton 1971, Shetsen 1990). Surficial deposits are generally not an important source of water, except in areas where sand and gravel have buried pre-glacial valleys (Le Breton 1971). These buried valleys are important sources of groundwater and may have aquifers of glacial or pre-glacial origin. To the north of the Battle River basin are the Beverly, Vegreville, and Vermilion channels which flow in north easterly direction; the Red Deer channel flows from west to east and follows the present Battle River basin (Kamac Consultants Ltd. 1986, Maslowski-Schutze et al. 1986).

Hydrochemistry of groundwater is characterized by low levels of dissolved solids (<500 ppm) in the western part of the basin and an eastward increase to 1000 ppm or more (Le Breton 1963, 1971). Groundwater is primarily of the sodium bicarbonate type although some areas have magnesium bicarbonate water (New Norway-Strome Transect) and other areas, mostly in the eastern portion of the basin, have very high sulphate concentrations (Le Breton 1971, Kamac Consultants Ltd 1986).

According to Hackbarth (1975) the Battle River in the Wainwright area receives groundwater discharge from local flow systems but not from regional systems and the Battle River valley does not act as a major discharge area.

3.3 HYDROLOGY AND LAKE WATER QUALITY

The Battle River is located in east-central Alberta and West Central Saskatchewan. From its source in Battle Lake, it flows in an easterly direction over approximately 800 km to the Alberta-Saskatchewan border. In Saskatchewan it continues its easterly route over nearly 300 km to its confluence with the North Saskatchewan River, a tributary of the Saskatchewan Nelson River system (Figure 1). At its confluence with the North Saskatchewan River, at the towns of North and South Battleford, the Battle River drains an area of 30,000 km^2, with approximately 25,000 km^2 in Alberta.

Total elevation drop from Battle Lake to the Saskatchewan border is approximately 300 m. The channel gradient averages less than 0.4 m/km and the only distinct break in the shallow river gradient occurs in the Gwynne area (Figure 3). In this area the river drops about 35 m over only 40 km into the deeply incised Gwynne channel created some 10,000 years ago by large meltwater outflows from post glacial Lake Edmonton (Planning Division 1981). The Battle River follows this meltwater channel for the remainder of its course.

The Battle River drains 44% of the 57,600 km^2 drained by the North Saskatchewan River in Alberta, but annual runoff represents only 3.5% of the average yield of the North Saskatchewan. There are several reasons for this low yield.

Unlike most other major rivers which flow from west to east in Alberta, the Battle River does not originate in the mountains or the foothills. Thus, the hydrologic regime in the river is not influenced by glacial meltwater, but by local runoff (spring melt, rain storms), groundwater flow and supply from tributaries, lakes, and reservoirs (i.e., Battle, Pigeon, Samson, Coal, and Driedmeat lakes and the Forestburg reservoir).

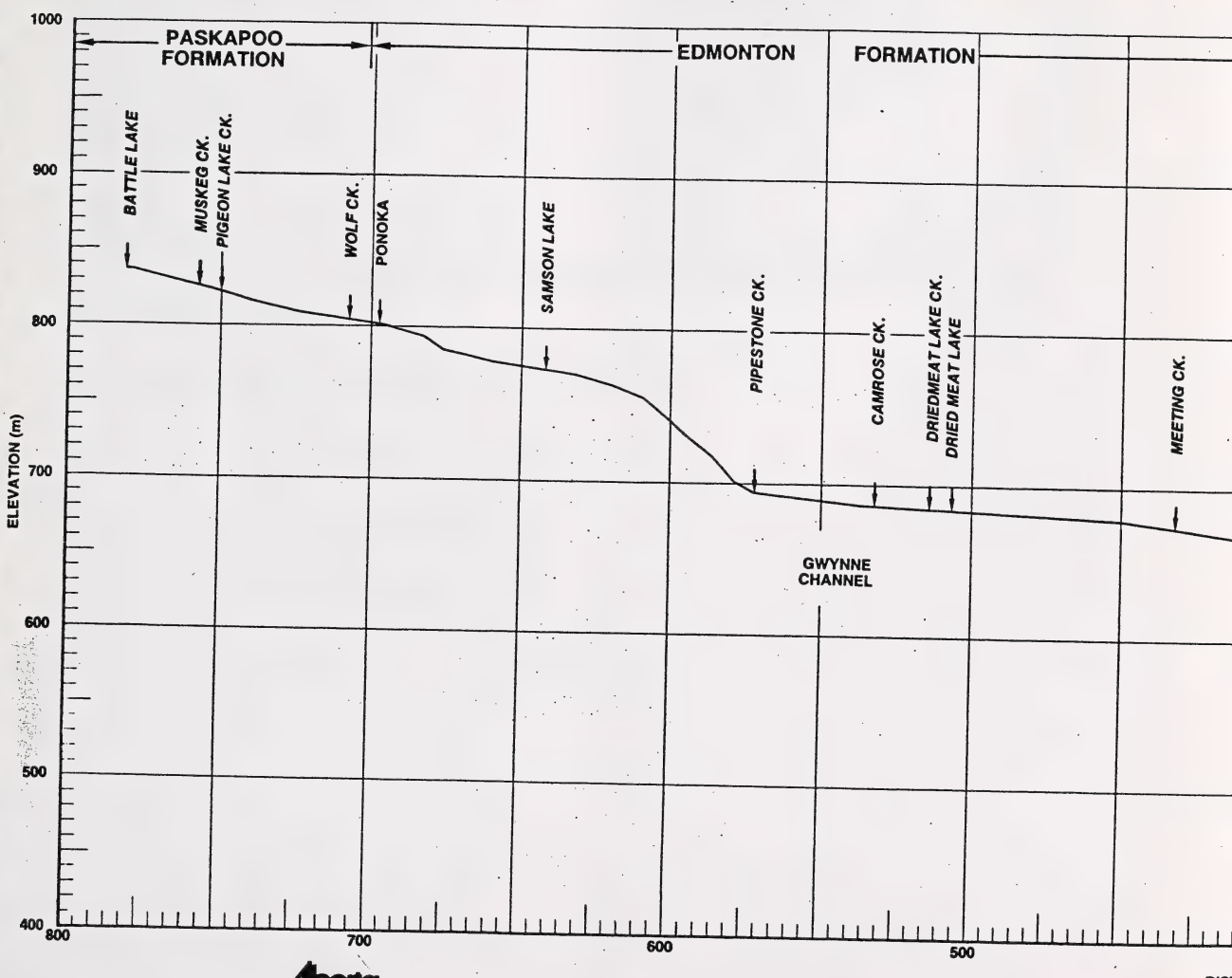
Many of the small tributaries to the Battle River contribute less than 2% of the annual yield (e.g., Battle, Pigeon, Camrose, Bigknife, Grattan, Buffalo, Grizzly Bear, and Blackfoot creeks) and only eight tributaries contribute 4% or more (Table 5).

The topography of the basin also contributes to the lower yields. One fifth of the Battle River basin in Alberta consists of blind drainage areas which do not contribute to surface flows whereas much of the remaining 20,000 km^2 have a fairly flat topography and are covered with small lakes and sloughs with low and variable surface yields (Planning Division 1981).

Another feature which distinguishes the Battle River from many other rivers in Alberta is the presence of several lakes which are actually widened portions of the river channel. Their presence along the course of the river attenuates and delays fluctuations in river discharge. Limnological characteristics for most of the lakes are presented in Mitchell and Prepas (1990).

Samson Lake, east of Ponoka, is a large marshy and shallow area through which the river meanders without following a well defined channel. There are no flow control structures on this lake.

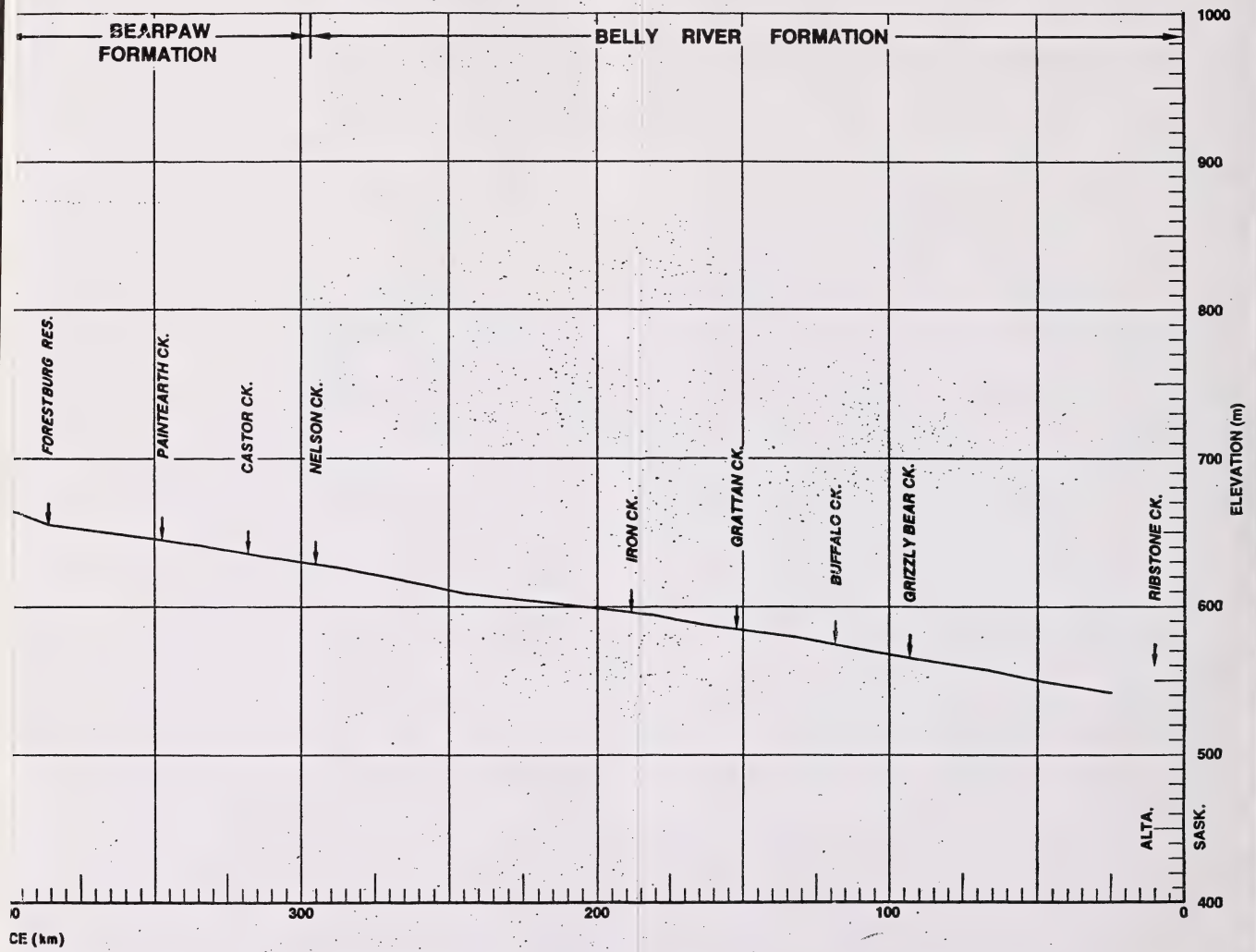
Driedmeat Lake, south of Camrose, is a large narrow natural lake formed by a widening of the river channel (surface area 16.5 km^2, average depth 2.2 m). With summer peak phosphorus and chlorophyll *a* concentrations exceeding 1 mg/L and 100 µg/L, respectively, Driedmeat Lake is one of the most hypereutrophic lakes in Alberta (Alberta Environment, unpublished data; Mitchell and Prepas 1990).



Alberta ENVIRONMENT

SOURCE : TECHNICAL SERVICE DIVISION

FIGURE 3. LONGITUDINAL



ROFILE OF THE BATTLE RIVER

Table 5. Hydrologic information for tributaries to the Battle River

TRIBUTARY	PERCENT OF MEAN ANNUAL RUNOFF IN BATTLE RIVER (1)	EFFECTIVE DRAINAGE AREA (in km^2)
Wolf Creek	5	760
Pipestone Creek	8	1256
Driedmeat Creek	4	1066
Meeting Creek	7	1141
Paintearth Creek	4	423
Castor Creek	4	412
Iron Creek	6	2605
Ribstone Creek	7	3351

From Planning Division 1981

(1) Expressed as a percent of the total runoff of the Battle River

In 1975 a fixed crest weir was constructed on the outlet of the lake to stabilize lake levels. When lake elevation is below the top of the weir, (usually by July or August), flow through the fish ladder provides 0.2 m^3/s continuous flow. Average retention time is short (0.1 year); but varies greatly with fluctuations in river discharge (Mitchell and Prepas 1990).

The Forestburg Reservoir, also called Battle River Reservoir, was created in the mid-1950's to provide cooling water for the adjacent thermal electric generating plant operated by Alberta Power Limited. The company is required by licence (Water Resource Administration Division, Alberta Environment) to supply minimum flows downstream of the reservoir. These minimum flows depend on the river discharge recorded at a Federal gauging station upstream of the reservoir (Table 3). During spring runoff, when river flows exceed or equal 5 c.f.s. (i.e., 0.142 m^3/s), minimum outflow must be 5 c.f.s.. Outflow must equal incoming flows during the summer when river discharge drops between 2 and 5 c.f.s.. At low flows (river discharge <2 c.f.s. or 0.057 m^3/s) minimum outflow must be 2 c.f.s.. In practice, the water can spill unimpeded over the spillway and effective flow control occurs only when water levels drop below the spillway, at which time the required flow is passed through a bottom syphon fitted with various size orifice plates (pers. comm., Jim Luk, Water Resource Administration). The reservoir is approximately 5 km long with a maximum width of 0.5 km and a maximum depth of 8 m (MacLaren Engineers 1981).

Several other large lakes, some with lake level stabilization structures, are located in the Battle River basin. Battle Lake is a long narrow lake at the head of the Battle River. Its outlet is the Battle River. Pigeon Lake is located northeast of Battle Lake and drains via Pigeon Lake Creek to the Battle River. There is a weir and fish ladder as flow control structures on the outlet of the lake (Mitchell and Prepas 1990). Since the construction of an earth embankment dam on Coal Lake in 1972-73, Pipestone Creek flows into Coal Lake and is also its main outlet. The dam has been operated for flow augmentation. Because Pipestone Creek flows through the southern portion of the lake, most of the water is "short circuited" and the effective retention time is likely much longer than the 1.2 year calculated for the lake (Mitchell and Prepas 1990).

Some lakes in the basin are effectively located in land-locked areas and do not drain to the Battle River (e.g., Red Deer Lake, Bittern Lake, Wavy Lake). Miquelon lakes used to drain to the Battle River, but as a result of declining lake levels there has been no outflow for the last 50 years (Mitchell and Prepas 1990).

Typically, flows in the Battle River are low during most of the year. In April and May, flow increases rapidly and for a short time as a result of snowmelt and local runoff. Hydrographs for 1989 and 1990 show that flows in 1989 were close to median values at the three continuous monitoring sites

(Figure 4a and b). In 1990 spring runoff was generally above average and heavy rains in the upper portion of the basin resulted in summer flows which were considerably above average. The effect of summer rain storms was particularly noticeable at Ponoka (Figure 4a and b).

Hydrographs for Iron Creek (Figure 4d) in 1990 also suggest that spring and summer runoff were above average in 1990. Hydrographs for Ribstone Creek (Figure 4c and d) reflect the intensive management of the creek for water fowl habitat enhancement and irrigation which results in a more even distribution of flows over the spring and summer than in the Battle River or its other tributaries.

Average travel time from source to confluence was estimated at 23 days (De Boer 1986). Data from 1990 suggest that this estimate applies to high flow conditions since the increased discharge which occurred at Ponoka as a result of summer storms was recorded nearly 20 days later at Unwin. Travel time under low flow conditions is probably much longer.

3.4 BASIN DEVELOPMENT

3.4.1 Land Use

The Battle River basin has a relatively sparse population which is split almost evenly between urban and rural areas. Stanley Associates Engineering Ltd. (1985) estimated that of the 98,000 inhabitants of the study area in 1983, approximately two-thirds lived in the upper portion of the basin. Of the 42 municipalities in the basin, only 12 have a population of 1,000 or more. Most of these larger municipalities are located in the upper portion of the basin. Camrose is the largest with 13,000 inhabitants followed by Wetaskiwin, which has more than 10,000 residents. Lacombe, Ponoka, and Stettler have populations greater than 5,000. Wainwright is the only municipality in the lower portion of the basin which has more than 5,000 inhabitants. This distribution is influenced by the proximity to the north-south Alberta transportation corridor and by the relatively better soil quality in the upper basin.

The economy of the basin is almost exclusively based on agriculture, natural resource industries, and supporting service sectors. Major agricultural crops include wheat, barley, oats, canola and hay; the livestock industry is also important in the basin. There are approximately 900 cattle, 1,000 hog, and 50 poultry operations (M. Bennet, ESD, Lethbridge, pers. comm.) which produce about one-tenth of the provincial total (Table 6). The livestock industry and forage crop production tends to be more intensive in the western portion of the basin (County of Ponoka, and Wetaskiwin, Lacombe). Farms are larger and grain crops are more prevalent in the eastern portion of the basin (County of Flagstaff and M.D. 61), (Table 6).

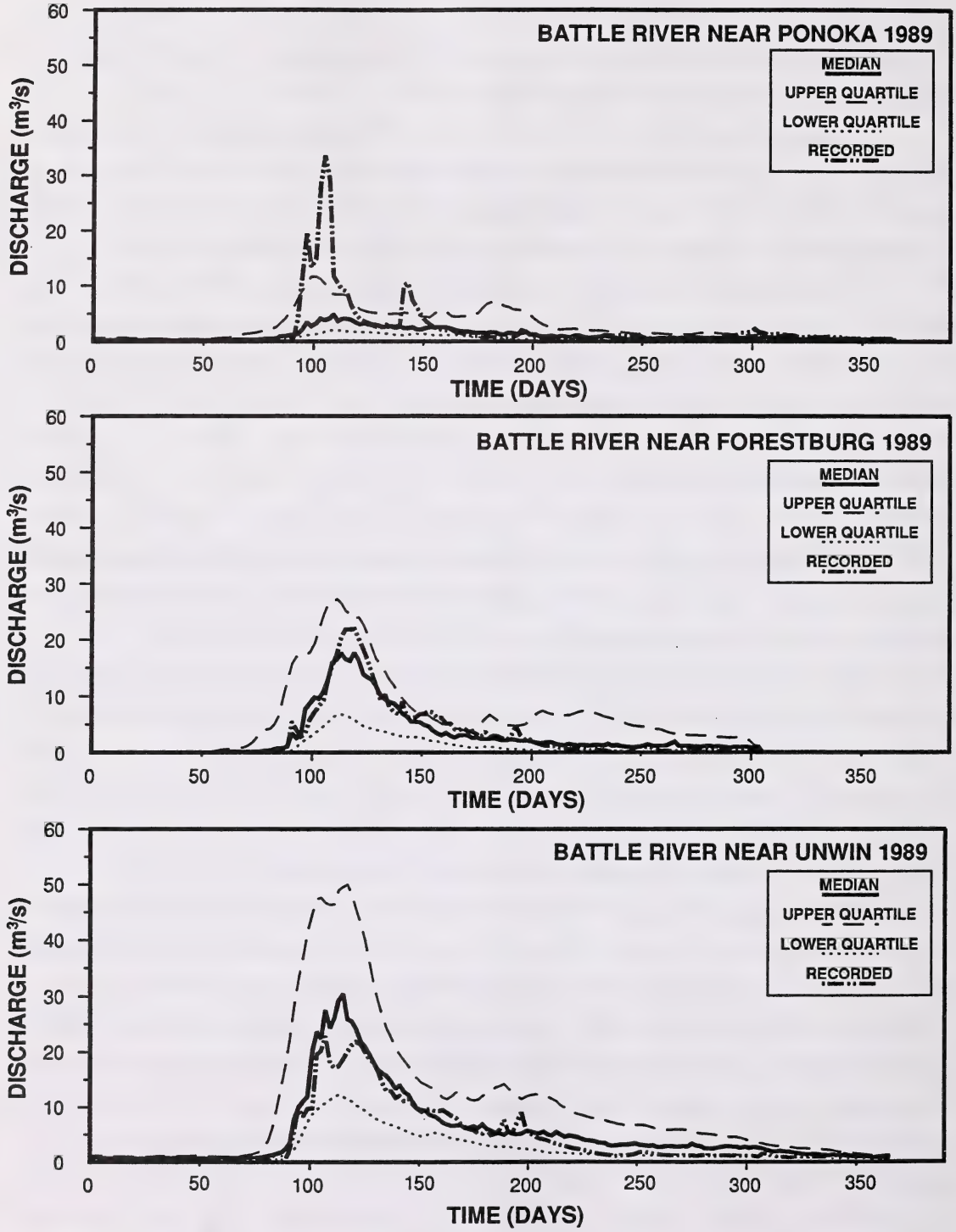


FIGURE 4a. Hydrographs for the Battle River and some of its tributaries.

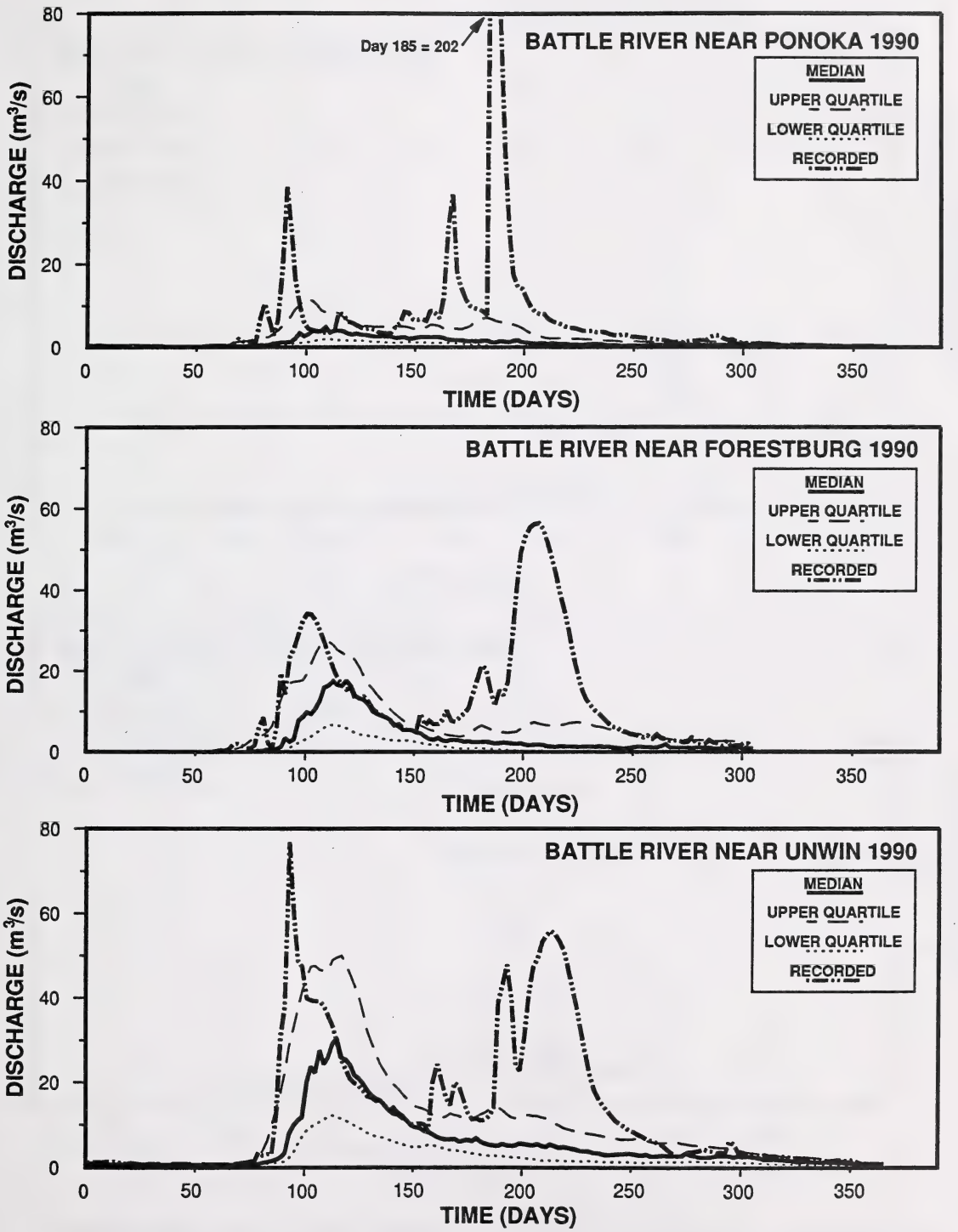


FIGURE 4b. Hydrographs for the Battle River and some of its tributaries (continued).

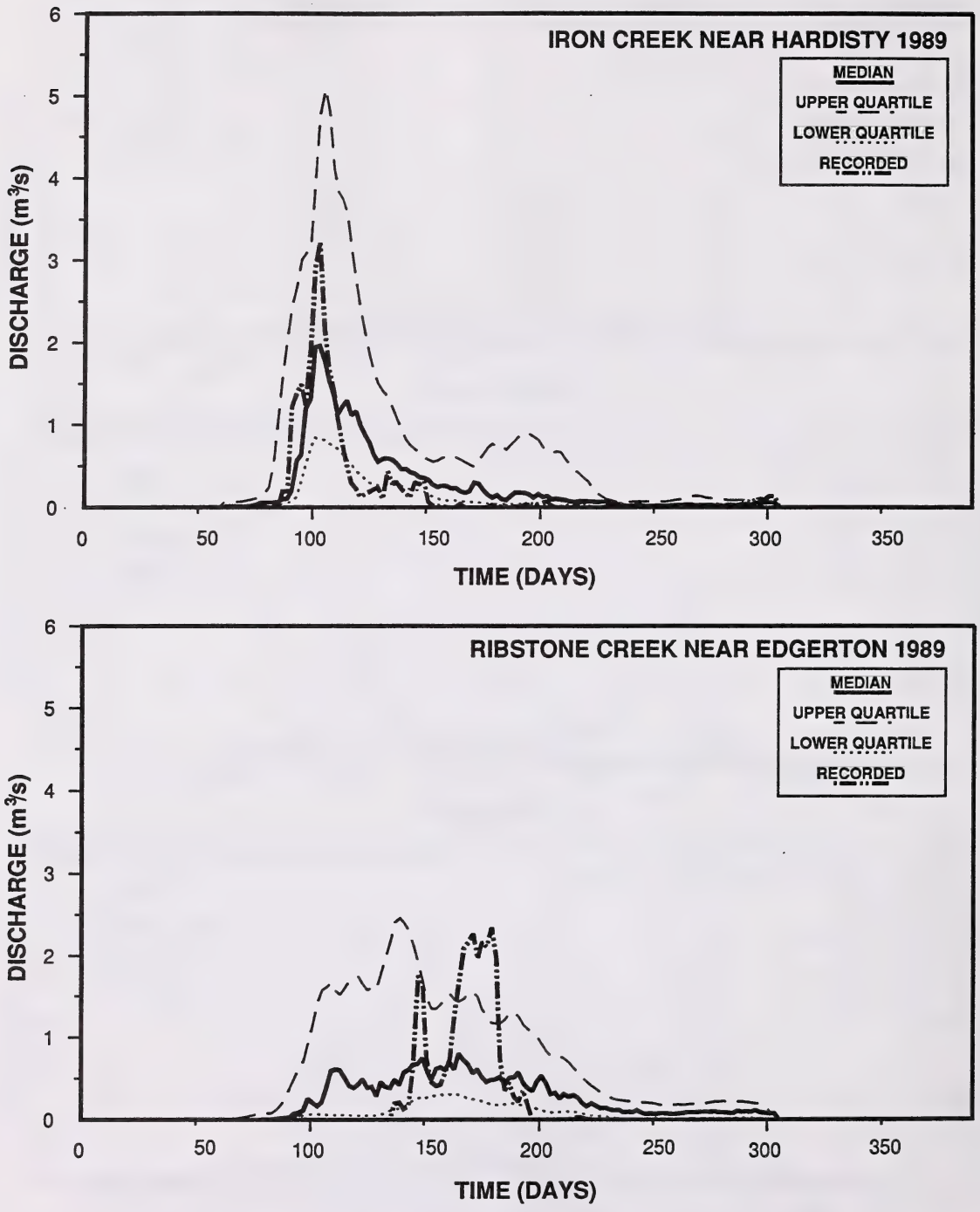
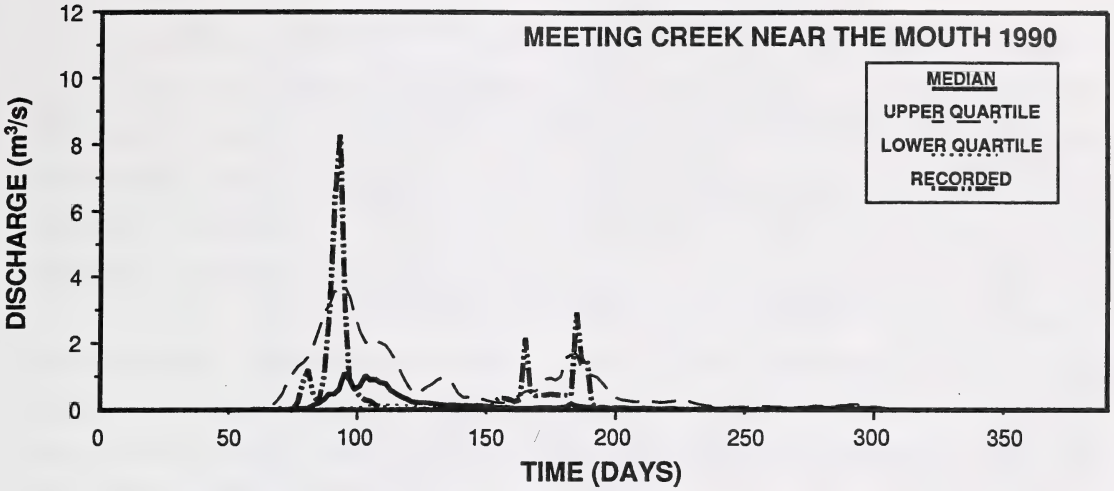
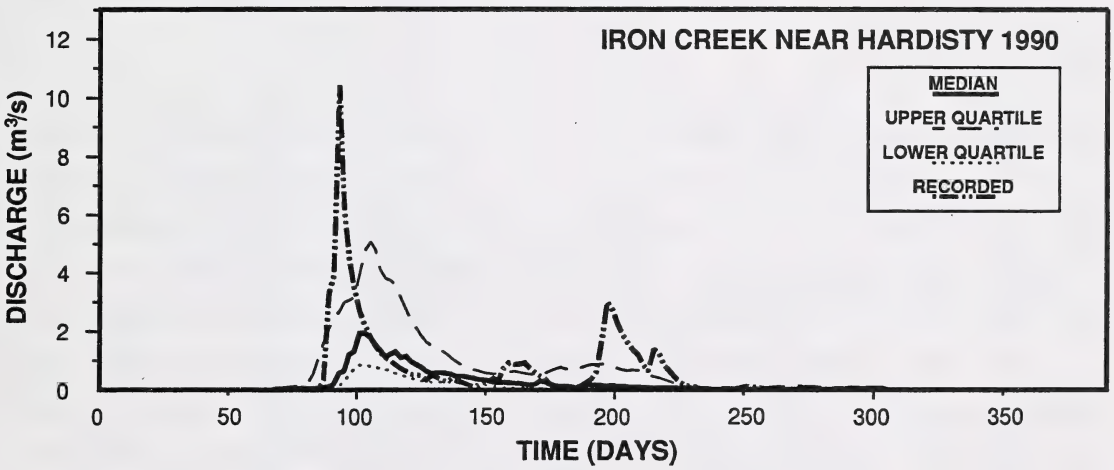


FIGURE 4c. Hydrographs for the Battle River and some of its tributaries (continued).





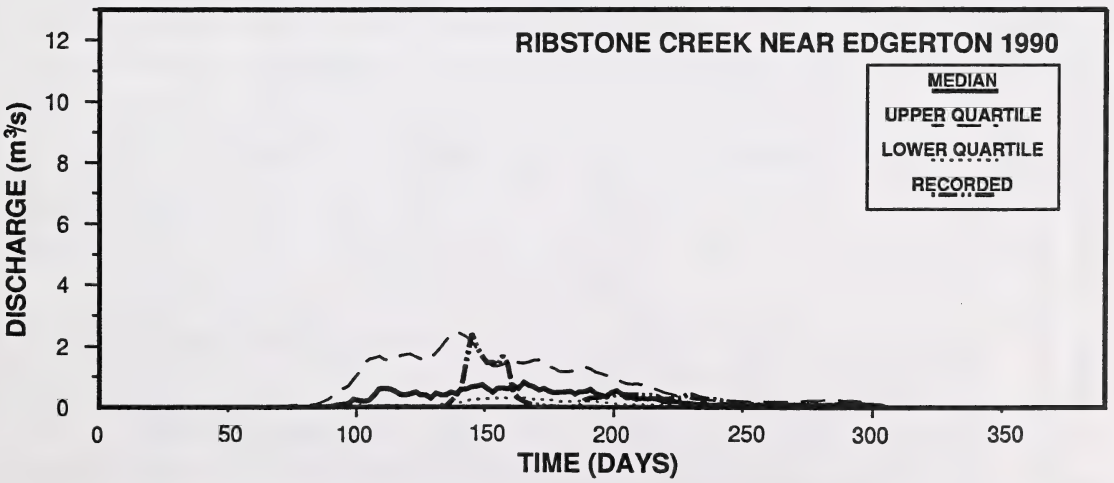


FIGURE 4d. Hydrographs for the Battle River and some of its tributaries (continued).

Table 6. Summary of agricultural land use and livestock production in counties and municipal districts from the Battle River Basin.

	PONOKA	WETASKIWIN	LEDUC	CAMROSE	FLAGSTAFF	M.D. 61	ALBERTA
Land Use in 1986							
Farmland Area (in acres)	638 964	669 407	745 095	832 663	1 013 076	876 563	51 040 463
Improved Land (1)	75%	68%	75%	82%	80%	65%	62%
Land in Crops (1)	54%	46%	58%	66%	66%	48%	44%
Land in Summer Fallow (1)	2%	3%	4%	8%	9%	10%	10%
Improved Pasture (1)	17%	16%	11%	6%	3%	6%	7%
Tame Hay (1)	20%	18%	23%	8%	2%	3%	7%
Livestock Production							
Chicken Production 1985	63 736	NA	1 435 893	1 940 162	114 620	14 131	29 543 868
Turkey 1985	1 161	98 372	901	NA	590	2 097	1 248 252
Cattle and Calves 1986	129 937	90 731	88 349	66 274	53 675	51 422	3 827 143
Dairy Cows 1986	6 372	5 616	13 805	4 318	1 388	1 289	124 204
Beef Cows 1986	40 173	30 053	24 153	21 414	18 600	20 046	1 321 556
Pigs 1986	48 784	37 126	29 840	37 485	14 596	18 076	1 454 824
Number of Farms	1 362	1 374	2 001	1 446	1 011	671	57 777
Average Size of Farms (in acres)	469	487	372	576	1 002	1 196	883

(1) % of total farm land area

Source: Census of Agriculture 1986
Alberta Agriculture Statistics Branch

The upstream portion on the basin (County of Wetaskiwin, Ponoka, Lacombe) was subjected to considerable land clearing between 1930 and 1976. Woodland areas and unimproved lands have diminished by 50% or more, whereas areas converted to field crops or improved pasture have increased by 50% and 100%, respectively (Stolte and Herrington 1980). Additional land continues to be brought into production at a rate which is close to the provincial average of 8% (Battle River Regional Planning Commission, spring 1988).

There are four large deposits of sub-bituminous coal which represent 18% of the remaining recoverable surface sub-bituminous coal reserves in Alberta (Stanley Associates Engineering Ltd. 1985). Current coal production is mainly in the Paintearth Creek drainage basin, south of the Battle River. The Battle River basin is also a mature oil and gas producing region with ten major producing oil fields either totally or partly contained within the basin.

3.4.2 Water Use

Water from the Battle River basin is used for consumptive (municipal, industrial, agricultural supply) and non-consumptive (recreation, power generation) purposes. According to Stanley Associates Engineering Ltd. (1985), the most significant water use in the basin is by Alberta Power Ltd., representing about 94% of the total licensed use in the basin (Table 7). The power plant uses the water from the Forestburg Reservoir for cooling purposes and approximately 98% of this water is returned to the river. Other important water uses of surface or groundwater sources are urban (municipal), agricultural (livestock and irrigation) and, increasingly, oil-well injection (Table 7). Most municipalities in the Battle River basin use groundwater as a source of raw water. Exceptions are Wetaskiwin which draws water from Coal Lake and Camrose which uses Driedmeat Lake as a source of municipal water. Camrose's situation is unique in the sense that the raw water intake is located downstream of the wastewater discharge point of several large municipalities, including its own. Ducks Unlimited has a considerable number of projects in the basin, particularly on Ribstone Creek. Angling is only moderately and locally popular in the Battle River. Most recreational activity is restricted to larger lakes such as Pigeon, Coal, and Driedmeat Lakes.

3.4.3 Potential Sources of Pollution

3.4.3.1 Point Sources

The main point-source discharge in the basin is municipal wastewater. In 1989, Environmental Sciences Division (AEP) lists 42 municipalities with licensed wastewater treatment facilities

Table 7. Licensed water use (1984) in the Battle River basin.

USER	WITHDRAWAL (in dam^3)		
	SURFACE	GROUND	TOTAL
Urban	11 507	5 813	17 321
Stock Water	2 626	54	2 680
Feed Lots	35	1 654	1 689
Agriculture	10 125	0	10 125
Water Fowl	2 386	0	2 386
Lake Stabilization	454	0	454
Oil Injection	7 159	2 007	9 166
Alberta Power	683 472	0	683 472
Other	3 334	109	9 443
TOTAL	727 098	9 637	736 735

From Stanley Associates Engineering Ltd. (1985)

in the basin. Two have continuous discharges (Wetaskiwin to Town Creek, and Wainwright to Bushy Head Lake); 29 discharge to the Battle River or its tributaries in spring and/or fall; 11 have sufficiently large storage capacities and do not discharge. Based on wastewater volumes reported by all municipalities, the average total volume of wastewater produced in the Battle River basin amounts to 11,500 dam^3/yr. Technically, this corresponds to a continuous production of 0.365 m^3/sec. Volumes actually discharged to the Battle River or its tributaries will be higher than this average in spring and fall when most municipalities discharge their effluent, and much lower in summer or winter when few or no municipalities discharge. Average daily flows for the largest municipalities are shown in Table 8; additional data are shown in Appendix 8. The time period during which municipalities discharge their wastewater ranges from two to three months in spring and fall (e.g., Figure 2).

Most industries in the Battle River basin do not have direct discharges to the Battle River. Notable exceptions are Alberta Power Ltd., which discharges ash pond effluent and condenser cooling water to the Forestburg Reservoir, and the Luscar Ltd. and Manalta Ltd. coal mines which discharge water from settling ponds to Paintearth Creek. (Table 8).

3.4.3.2 Non-Point Sources

Non-point source or diffuse sources of contamination are multiple in the Battle River basin, as they are in many other regions of Alberta. They include the potential transfer of contaminants from the atmosphere, groundwater and land.

Atmospheric transport and deposition of nutrients, metals, salts and man-made organic compounds, such as pesticides, are ubiquitous and has been well documented in many parts of the world (e.g., Moore and Ramamoorthy 1984, Moore 1990).

The potential for contamination of surface waters with contaminated groundwater has been examined for the coal mining area south of the Forestburg Reservoir by Trudel (1988). He showed that mine-spoil groundwater was significantly more saline than groundwater typifying pre-mining conditions. Arsenic, boron, copper, cobalt, and lead were also commonly detected in this mine-spoil groundwater. The deep sandstone aquifers within the Bearspaw Formation, which contribute significantly to the base flow in the river, are not likely impacted by surface mining. However, the shallow groundwater flow associated with springs along the river valley walls includes aquifers which contact the coal zone. Several of these springs have water quality characteristics which match those of mine spoil groundwater. Trudel (1988) estimated that the contribution of salt loads from these springs to the Battle River was of minor importance.

Table 8. Largest municipalities and industries discharging to the Battle River basin (1989-1990).

SOURCE	DISCHARGE FREQUENCY	DISCHARGE ROUTE	AVERAGE DAILY FLOW IN m^3/day
Municipal Discharge (1)			
Lacombe	S F (3)	Wolf Creek	1 937
Ponoka	S F	Battle River	1 591
Wetaskiwin	C	Town Creek	3 738
	S F	Pipestone Creek	
Millet	F	Pipestone Creek	260
Camrose	S F	Camrose Creek	4 851
Stettler	S F	Red Willow Creek	1 827
Viking	S F	Thomas Creek	847
Killam	F		272
Castor	S F	Castor Creek	422
Coronation	F	Ribstone Creek	489
Wainwright	C	Bushy Head Lake	2 872
Industrial Discharge (2)			
Alberta Power Ltd.			
Ash Lagoon Effluent		Forestburg Reservoir	11 037 (1989) 6 681 (1990)
Cooling Ponds/Canal		Forestburg Reservoir	No data
Luscar Ltd.		Paintearth Creek	No data
Manalta Coal Ltd. Vesta Mine		Paintearth Creek	No data

(1) From Standards and Approvals Division 1988
Municipalities with 1000 residents or more
(2) From Standards and Approvals Division Industrial Files
(3) S = spring, F = fall, C = continuous

The large number of gas and oil pipelines in the basin represents a real risk for surface water contamination if leaks or breaks in pipelines were to occur. The use of soil sterilants and pesticides at well sites also constitutes a risk, especially because many of these well sites are located very close to the Battle River or its tributaries.

Diffuse transport of soil particles, agrochemicals, and animal wastes can be anticipated in areas of intensive agricultural activity like the Battle River basin. Diffuse runoff from agricultural land is likely to be most intense during spring runoff and heavy summer rain storms.

Several intensive livestock operations (e.g., feedlots, hog or poultry farms) are located near the Battle River or its tributaries. Although these operations do not have licensed discharges to the river it is probable that during spring melt and heavy rains, runoff from their grounds enters the river either directly or indirectly after infiltration to groundwater. Pasture land and range land borders the Battle River in many locations and the river is a water source for the cattle. In most instances access to the water is uncontrolled and the passage of the animals contributes to bank slumping and erosion.

4.0 RESULTS AND DISCUSSION

4.1 GENERAL DATA EVALUATION

4.1.1 Flow Dependency

The relationship between flow and water quality variables was examined for long-term water quality data from the federal site at Unwin. Eighteen of the 43 variables tested were flow-dependent ($r>0.2$) and flow explained 50% or more of their variability (Table 9).

For the flow-dependent variables, concentrations of dissolved ions (sodium, magnesium, sulphate, chloride, bicarbonate) or related variables (specific conductance, alkalinity, hardness, total dissolved solids) were inversely correlated with flow, whereas variables related to particulate matter (non-filterable residue, turbidity, total particulate carbon, total nitrogen, total phosphorus, total nickel, vanadium, and zinc) were positively correlated with flows. This relationship is fairly typical for many rivers (e.g., Whitton 1975) and similar patterns have been described for other rivers of Alberta (e.g., Cross et al. 1986, Shaw et al. 1989, Shaw et al. 1992).

4.1.2 Long-Term Trends

Twenty-nine of the 44 variables tested for long-term trends did not show statistically significant monotonic trends over the period of record tested; ten (10) variables (i.e., true colour, hardness, TDS, sodium, magnesium, sulphate, TN, DN, phenolics and alpha-BHC) showed significant decreases; the

Table 9. Regressions of concentration ([x]) versus discharge (Q) for flow-dependent variables and flow-independent variables in the Battle River at Unwin.

FLOW-DEPENDENT VARIABLES	REGRESSION	r^2	df
Specific Conductance	Log [x]=6.945-0.176 log Q	0.64	182
NFR	[x]=1.391+8.757 Q	0.57	188
Turbidity	[x]=3.461+3.067 Q	0.64	189
Alkalinity	[x]=398.226-55.246 log Q	0.48	193
Hardness	Log [x]=5.640-0.155 log Q	0.48	181
TDS	Log [x]=6.492-0.189 log Q	0.64	188
Sodium	Log [x]=4.867-0.205 log Q	0.54	191
Magnesium	Log [x]=3.476-0.193 log Q	0.61	181
Sulphate	Log [x]=4.973-0.178 log Q	0.42	194
Chloride	Log [x]=3.124-0.300 log Q	0.63	193
Bicarbonate	Log [x]=6.180-0.205 log Q	0.67	183
TOC	[x]=12.870+0.419 Q-0.003Q^2	0.43	108
POC	[x]=0.713+0.237 Q	0.66	155
TN	[x]=0.789+0.50 Q-0.0002Q^2	0.57	156
TP	[x]=0.0475+0.009 Q	0.58	191
Nickel (total)	[x]=0.003+0.0006 Q-0.000002Q^2	0.65	117
Vanadium (total)	[x]=0.0005+0.0004 Q	0.60	116
Zinc (total)	[x]=0.0023+0.0007 Q	0.64	116

- Units are in mg/L, except for specific conductance (µS/m), true colour (RCU), turbidity (JTU), and discharge (m^3/s)
- All r significant at $P < 0.05$

FLOW INDEPENDENT VARIABLES		
Water Temperature	Chl *a*	Arsenic
PH	Total Coliform	Boron (diss.)
DO	Fecal Coliform	Manganese (diss.)
DOC	Cyanide	Aluminum (extr.)
DN	Phenolics	Barium (tot.)
(NO_2^-+NO_3^-)-N	*a*-BHC	Iron (diss.)
DP	*b*-BHC	Copper (tot.)
Silicate	True Colour	Chromium (tot.)
Potassium		
Calcium		

other five (5) (NFR, turbidity, DOC, POC, and aluminum) increased significantly (Table 10). A number of variables such as lead, mercury, and most pesticides were not tested for temporal trends because measurable concentrations were reported too infrequently to make meaningful evaluation of trends.

- The statistical validity of these results may be questioned for TDS, sodium, and magnesium because serial correlation persisted even when quarterly data were analyzed. As noted earlier (Methods) serial correlation increases the chance of erroneously recognizing trends (Type II errors).

- Although the statistical validity of the results for other variables is not affected by serial correlation, it is notable that changes over time (as indicated by the slope) are generally very small compared to in-stream concentrations. Notable exceptions are DOC, alpha-BHC and aluminum.

These results, their possible cause, and their implications to the quality of the Battle River are discussed in the following sections. Results presented in Table 10 compare quite closely to those published by El-Shaarawi et al. (1991) on trend analysis of selected water quality variables monitored at all PPWB sites, including the Battle River at Unwin site. In particular, the absence of trend in river discharge, dissolved phosphorus, and fecal coliforms, and the decline in TN, alpha-BHC and sulphate are noteworthy similarities.

Differences in handling values below the detection limit (eliminated from data set by El-Shaarawi et al. (1991); replaced by half the detection limit in this report) may have contributed to some of the differences. El-Shaarawi (1991) reported declining trends for total coliforms, total copper, and dissolved iron and no trend for sodium.

4.1.3 Mass Loads

4.1.3.1 Mass Loads at Survey Sites

Average daily mass loads were calculated for each mainstem site and each tributary site (period May 1989 to April 1990). Data for winter surveys were not included because flow data were unavailable. The mass loads provide an indication of mass transport during the open water period of an entire year of near average river flows.

Mass loads were also calculated for mainstem and tributary sites sampled during 1990 surveys. They provide an indication of the importance of tributary inputs to mass transport in the Battle River and also complement 1989 data with information on mass transport at higher than average river flows.

Table 10. Kendall test for long-term trends in data collected in the Battle River at Unwin.

VARIABLE	PERIOD OF RECORD TESTED	KENDALL TAU	SLOPE (1) (2)	TREND
Flow	(1974-1990) Q	-0.056	-	none
Water Temperature	(1974-1990) Q	0.997	-	none
PH	(1974-1990) Q	0.904	-	none
DO	(1974-1990) Q	-1.231	-	none
Specific Conductance (4)	(1974-1990) Q	0.266	-	none
NFR (4)	(1974-1990) M	2.382	0.38889	increase
Turbidity (4)	(1974-1990) M	4.721	0.56785	increase
True Colour	(1981-1990) M	-2.233	-1.58656	decrease
Alkalinity (4)	(1974-1990) Q	-0.044	-	none
Hardness (4)	(1975-1990) Q	-2.461	-0.01040 (3)	decrease
TDS (4)	(1975-1990) Q	-3.630	-0.01559 (3)	decrease (5)
Sodium (4)	(1974-1990) Q	-2.916	-0.01757 (3)	decrease (5)
Magnesium (4)	(1975-1990) Q	-2.847	-0.01454 (3)	decrease (5)
Calcium	(1974-1990) Q	-1.869	-	none
Potassium	(1974-1990) Q	1.165	-	none
Sulphate (4)	(1974-1990) Q	-3.323	-0.02594 (3)	decrease
Chloride (4)	(1974-1990) Q	-0.713	-	none
Bicarbonate (4)	(1974-1990) Q	-1.070	-	none
TOC (4)	(1981-1990) Q	1.433	-	none
DOC	(1978-1990) Q	2.028	0.16667	increase
POC (4)	(1977-1990) M	2.937	0.03788	increase
TN (4)	(1977-1990) Q	-2.192	-0.02083	decrease
DN	(1976-1990) Q	-2.488	-0.01296	decrease
$(NO_2^-+NO_3^-)$-N	(1974-1990) Q	-0.721	-	none
TP (4)	(1976-1990) Q	-1.384	-	none
DP	(1976-1990) M	-0.997	-	none
Silicate	(1974-1990) Q	-2.683	-	none
Chl *a*	(1980-1990) Q	-1.307	-	none
Total Coliform	(1975-1990) Q	-1.233	-	none
Fecal Coliform	(1974-1990) Q	0.660	-	none
Cyanide	(1975-1990) M	-1.406	-	none
Phenolics	(1975-1990) Q	-3.008	-0.00017	decrease
alpha-BHC	(1975-1990) Q	-4.770	-0.00029	decrease
Arsenic (diss.)	(1974-1990) Q	-0.887	-	none
Boron (diss.)	(1974-1990) Q	-0.872	-	none
Manganese (diss.)	(1980-1990) Q	-0.647	-	none
Aluminum (extr.)	(1974-1990) Q	2.348	0.01286	increase
	(1981-1990) Q	2.760	0.01563	increase
Barium (tot.)	(1980-1990) M	0.323	-	none
Iron (diss.)	(1981-1990) Q	0.551	-	none
Chromium (tot.)	(1983-1990) Q	0.062	-	none
Copper (tot.)	(1980-1990) Q	-0.528	-	none
Nickel (tot.) (4)	(1980-1990) M	-0.443	-	none
Vanadium (tot.) (4)	(1974-1990) M	1.248	-	none
Zinc (tot.) (4)	(1980-1990) M	0.396	-	none

(1) Slope is given only for significant ($P < 0.05$) Kendall Tau Statistics
(2) Slope indicates significant increase or decrease in mg/L.yr except for turbidity (JTU/yr) and true colour (RCU/yr)
(3) Slope indicates significant increase or decrease in log (mg/L.yr)
(4) Trend tested on flow-adjusted data
(5) Questionable statistical validity of trend because of persistent serial correlation
Q = quarterly data tested; M = monthly data tested

A number of factors must be considered in the appraisal of the results:

1. Because 1989 loads are based on data for eight surveys, they may reflect mass transport more accurately than 1990 loads, which are based on data from four surveys or less (some tributaries were sampled only once).

2. Events of short-term duration (i.e., spring melt, surface runoff, wastewater discharges) and on-stream lakes may affect river flows and water quality locally. Depending on the timing of the surveys, the sampling during these events may or may not have been adequately representative and consequently their relative importance could be somewhat distorted.

3. The surveys were not synchronized with time of travel, which is very long in the Battle River. As a result, mass loads do not necessarily represent mass balances.

4. Actual flow measurements rather than balanced flows were used in the calculations.

5. Concentrations below method detection limits were replaced by zero values and some mass load estimates may be under-estimated.

6. Some constituents are non-conservative; their concentrations change as a result of in-stream processes.

Mass loads are summarized in Table 11. Differences in mass loads between two sites are expressed as a percent of the load at the most upstream of the two sites. Tributary loads are expressed as a percent of the load at the mainstem site immediately upstream. Concentration and flow data are given in Appendix 1 and 2 respectively, actual mass loads are given in Appendix 7.

The largest relative changes in mass loads of major ions, nutrients and metals occurred in the upstream portion (i.e., upstream of Driedmeat Lake or from site 1 to site 6), and in the lower portion of the basin (i.e., from site 10-11 to site 15). Mass loads changed comparatively little for many constituents in the center portion of the basin (site 7 to 10). These overall changes in mass loads primarily reflect changes in river flows and, for some constituents such as nutrients, the influence of point sources. It is noteworthy that average flows at the time of water quality sampling downstream of Samson Lake (site 4) were lower than upstream (site 3) and that this difference accounts for the apparent trapping of materials (mass load deficit) by the lake. Lower average flows were also recorded downstream of Driedmeat Lake (site 7) and at Highway 872 (site 10).

Absolute values of mass loads of most 'conservative' elements (e.g., major ions, TP, metals) increased in downstream direction and reached their highest values at site 14 (Unwin) or site 15 near the mouth (Appendix 7). For these constituents mass loads at Unwin were 5 to 20 times greater than at Highway 611 (site 1). Mass loads for non-conservative elements (e.g., some forms of nutrients, Chl *a*, bacteria, BOD) tended to reach a plateau downstream of Driedmeat Lake.

Table 11. Increment in mass load expressed as percent of upstream (site 1) load.

STATION	CODE	RIVER FLOW 97160S	ALK. TOT. 10101L	HARD. TOT. 10605L	TDS 00205L	CA 20107L	MG 12105L	NA 11103L	K 19103L	HCO3 06202L	CL 17203L	SO4 16306L	F 09107L	SILICA 14107L	BOD 08202L	COD 08304L	NFR 10401L	FR 10451L
A. MAINSTEM SITES (MAY 1989 - APRIL 1990)																		
BATTLE RIVER AT:																		
HWY 611 (SITE 1)	00AL05FA0250	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
HWY 53 (SITE 2)	00AL05FA0280	87.3	118.8	121.4	123.0	111.8	139.7	135.7	162.1	112.1	139.4	154.6	115.8	66.4	124.8	131.2	428.1	121.1
HWY 2A (SITE 3)	00AL05FA0413	33.9	40.7	41.2	46.9	40.6	41.8	56.7	43.3	33.5	133.9	86.9	69.2	26.2	53.4	44.5	-19.0	46.2
D/S SAMSON L. (SITE 4)	00AL05FA0500	-3.5	-17.0	-26.6	-11.2	-38.0	-8.1	13.8	25.3	-24.8	32.5	20.0	11.6	88.2	91.9	49.5	97.5	-5.4
HWY 21 (SITE 5)	00AL05FA0700	48.6	59.2	64.7	80.6	72.7	56.1	90.0	76.1	82.9	138.5	177.1	79.9	20.3	32.9	48.1	291.0	98.9
D/S CAMROSE CR. (SITE 6)	00AL05FA0750	4.1	5.9	11.0	8.9	14.4	6.6	7.7	3.1	8.8	5.3	18.0	-2.4	27.9	-16.4	0.6	-8.2	8.9
HWY 850 (SITE 7)	00AL05FA1000	-0.5	3.4	6.8	7.5	10.3	2.5	3.3	22.0	-2.2	20.2	16.1	14.6	37.9	14.9	10.6	-0.7	-1.7
U/S FORESTBURG RES. (SITE 8)	00AL05FC0660	3.8	1.1	-0.3	8.8	0.7	-1.7	19.3	6.1	2.3	-4.0	29.4	6.2	14.9	-8.8	-23.1	-39.1	3.1
HWY 861 (SITE 9)	00AL05FC0680	12.2	9.4	5.3	13.7	1.6	10.4	20.7	10.2	13.0	24.1	20.5	4.0	-31.3	-6.4	10.4	122.3	27.9
HWY 872 (SITE 10)	00AL05FC1000	-1.6	14.0	23.4	19.6	19.1	28.9	17.3	1.6	11.8	3.6	33.7	13.1	5.6	-26.0	-7.1	62.9	17.3
D/S HARDISTY (SITE 11)	00AL05FB0500	4.5	11.8	9.6	3.7	9.1	10.6	0.4	-5.3	12.1	10.7	-7.5	-3.0	14.6	2.6	-1.3	-15.9	2.8
HWY 41 (SITE 12)	00AL05FE0400	0.2	7.3	-4.5	4.4	-6.0	-2.7	16.1	-9.6	4.3	-0.5	-1.6	-1.5	10.8	2.2	-13.8	2.5	6.2
HWY 897 (SITE 13)	00AL05FE0850	15.7	22.7	16.7	28.1	9.9	24.7	37.3	17.5	21.8	31.2	38.0	19.1	-17.3	11.6	43.2	140.6	47.5
UNWIN (SITE 14)	00SA05FE1000	4.3	8.1	10.8	8.7	10.9	10.7	7.1	5.1	8.2	14.4	9.3	6.7	26.6	15.5	0.2	-3.9	8.1
HWY 40 (SITE 15)	00SA05FF1000	20.8	12.2	21.7	18.6	20.8	22.7	14.1	21.3	11.2	10.6	32.9	19.5	6.4	2.3	25.4	40.5	15.2
	00SA05FF1000																	
B. MAINSTEM SITES (APRIL 1990 - OCTOBER 1990)																		
HWY 611 (SITE 1)	00AL05FA0250	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
HWY 53 (SITE 2)	00AL05FA0280	73.3	60.8	63.8	62.3	56.6	76.6	50.9	161.0	60.8	65.5	73.3	77.6	399.6	60.3	78.6	221.0	81.2
HWY 2A (SITE 3)	00AL05FA0413	38.8	31.2	32.8	35.2	32.5	32.6	30.2	50.8	28.7	130.7	60.7	57.9	33.1	51.0	47.7	21.2	43.0
D/S SAMSON L. (SITE 4)	00AL05FA0500	-32.4	-20.8	-24.8	-15.6	-25.2	-23.9	7.7	-25.2	-22.8	13.9	29.1	-11.6	-78.9	-17.7	-9.4	-26.6	-24.7
HWY 21 (SITE 5)	00AL05FA0700	73.6	83.5	81.6	89.3	82.9	79.7	100.9	79.7	88.8	99.1	125.3	85.0	80.0	92.9	80.0	394.9	121.4
D/S CAMROSE CR. (SITE 6)	00AL05FA0750	5.7	5.8	11.2	16.7	9.1	14.7	19.3	12.1	5.6	62.6	61.0	306.6	53.5	12.6	7.3	18.9	14.7
HWY 850 (SITE 7)	00AL05FA1000	-6.2	5.0	7.5	7.2	5.9	9.9	9.8	8.1	6.5	-3.8	15.2	-72.6	-26.2	13.1	25.5	-18.5	1.5
U/S FORESTBURG RES. (SITE 8)	00AL05FC0660	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	-0.1	-0.2	-0.3	-0.1
HWY 861 (SITE 9)	00AL05FC0680	17.4	0.1	2.0	1.4	4.1	-0.8	-1.8	12.8	-2.0	-11.7	-100.0	4.5	-18.5	-14.1	23.8	136.5	29.6
HWY 872 (SITE 10)	00AL05FC1000	-1.1	0.3	-0.2	1.5	0.1	-1.1	3.4	-1.1	0.6	-7.0	0.0	3.4	10.9	-5.2	5.4	137.6	20.3
D/S HARDISTY (SITE 11)	00AL05FB0500	6.8	19.7	19.0	19.9	18.8	19.2	22.0	7.7	21.3	27.4	4.4	11.5	35.2	-0.5	-8.8	-34.2	5.7
HWY 41 (SITE 12)	00AL05FE0400	6.2	15.5	11.7	11.7	10.4	14.1	15.9	-0.5	15.7	-4.4	0.1	7.7	47.6	-16.2	-1.5	-7.2	0.3
HWY 897 (SITE 13)	00AL05FE0850	7.0	10.4	9.5	17.0	8.7	11.4	25.7	8.9	8.6	24.1	53.6	9.9	25.6	13.1	38.4	187.8	52.1
UNWIN (SITE 14)	00SA05FE1000	5.4	7.3	4.3	6.5	1.5	8.2	9.4	6.1	6.1	2.9	5.8	11.1	13.1	32.2	-3.6	-7.5	10.9
C. TRIBUTARIES (APRIL 1990 - OCTOBER 1990)																		
PIGEON L. CR.	00AL05FA0225	39.1	33.5	34.2	33.1	33.1	36.1	28.6	49.5	33.4	36.9	28.8	43.0	174.6	17.0	28.9	166.6	42.0
WOLF CR.	00AL05FA0287	18.2	30.1	33.6	35.1	36.8	28.5	36.6	21.6	30.1	141.2	72.7	40.4	21.1	22.1	23.1	5.5	29.4
PIPESTONE CR.	00AL05FA0600	68.7	74.0	70.0	81.7	72.9	65.1	98.9	92.5	77.4	125.9	111.3	94.7	150.2	83.3	82.4	149.0	92.1
CAMROSE CR.	00AL05FA0745	5.7	5.8	8.6	13.4	8.0	9.6	18.5	10.7	5.9	41.8	43.9	11.4	17.5	11.8	7.9	5.0	
MEETING CR.	00AL05FC0290	5.6	7.7	4.8	8.2	5.1	4.4	13.9	5.7	7.7	7.3	9.2	7.2	14.9	3.4	4.3	4.8	7.5
BIG KNIFE CR.	00AL05FC0400	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAINTEARTH CR.	00AL05FC0690	2.4	2.2	1.7	3.3	1.9	1.4	5.5	1.9	2.2	2.4	0.0	3.1	9.0	2.2	2.0	1.4	2.9
CASTOR CR.	00AL05FC0800	1.2	0.7	0.5	1.1	0.6	0.4	1.8	0.8	0.7	0.8	0.0	1.2	3.5	0.9	1.0	0.4	1.3
IRON CR.	00AL05FB0700	5.4	12.2	10.0	14.8	6.0	16.5	22.4	8.6	11.9	8.7	25.0	5.5	16.1	5.1	8.1	1.0	9.4
BUFFALO CR.	00AL05FE0500	1.3	1.7	1.7	2.2	1.1	2.6	2.9	0.4	1.7	0.2	4.5	0.8	1.2	0.5	0.7	0.0	1.5
GRIZZLY BEAR CR.	00AL05FE0600	0.0	0.1	0.1	0.1	0.0	0.1	0.2	0.0	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.1
RIBSTONE CR.	00AL05FE0875	2.6	3.8	3.5	3.1	2.8	4.4	3.1	1.7	3.7	1.6	1.7	4.0	2.9	1.7	2.3	0.1	1.7
BLACKFOOT CR.	00AL05FE0890	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0

Table 11. Increment in mass load expressed as percent of upstream (site 1) load. (continued).

STATION	CODE	T&L 06551L	O&G 06524L	PHENOL. MAT. 06537L	DOC 06107L	POC 06905L	PART.P 15901L	TOT.P 15421L	N-NH3 07562L	N-NO2+ N03 07105L	N-NO2 07205L	N-TKN 07021L	PART-N 07906L	CHL-A 06715L	COLIF. TOT. 36001L	COLIF. FECAL 36011L	AL EXTR. 13030L	AL DISS. 13109L
A. MAINSTEM SITES (MAY 1989 - APRIL 1990)																		
BATTLE RIVER AT:																		
HWY 611 (SITE 1)	00AL05FA0250	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
HWY 53 (SITE 2)	00AL05FA0280	156.0	-44.5	140.9	134.4	146.8	189.0	244.3	114.2	13.4	20.0	161.0	153.8	72.4	97.2	905.4	21.7	213.8
HWY 2A (SITE 3)	00AL05FA0413	42.3	33.9	48.8	43.1	16.8	56.2	67.0	106.6	69.1	92.7	40.4	27.5	337.8	-8.3	-56.8	-7.4	-90.0
D/S SAMSON L. (SITE 4)	00AL05FA0500	3.8	105.0	28.7	25.8	214.6	63.9	-16.5	-18.8	7.8	4.7	70.2	206.4	132.7	54.0	-23.9	-24.0	1130.3
HWY 21 (SITE 5)	00AL05FA0700	44.7	66.1	37.5	47.5	24.2	108.4	144.6	145.0	87.4	57.9	37.1	10.0	-7.6	38.0	427.5	484.8	-27.1
D/S CAMROSE CR. (SITE 6)	00AL05FA0750	18.7	47.9	-0.6	1.4	13.1	2.0	-13.7	33.2	-27.1	-38.8	8.5	5.2	3.1	2.8	-35.6	-36.5	366.3
HWY 850 (SITE 7)	00AL05FA1000	-19.3	-74.2	6.0	7.2	56.9	10.3	59.1	85.0	-0.9	39.2	11.7	76.9	57.3	122.2	165.2	-35.5	-22.7
U/S FORESTBURG RES. (SITE 8)	00AL05FC0660	-1.8	3.8	-18.3	-12.2	-45.7	-31.9	-48.6	-69.3	48.4	81.6	-21.9	-45.0	-3.6	-93.5	-90.6	16.2	42.0
HWY 861 (SITE 9)	00AL05FC0680	10.6	461.0	0.8	4.6	-26.0	23.7	14.8	23.9	44.8	37.4	-0.8	-8.5	-47.1	232.8	266.8	142.2	-22.7
HWY 872 (SITE 10)	00AL05FC1000	-21.8	-43.8	-13.4	-8.8	29.2	-2.4	-15.3	-36.6	-2.7	-33.6	-13.6	-19.1	-21.3	-44.6	-8.5	-17.0	219.8
D/S HARDISTY (SITE 11)	00AL05FB0500	2.5	9.7	-12.5	-4.8	49.6	-3.6	-10.7	4.0	-11.5	-38.1	-0.9	-5.1	12.9	-60.9	21.9	66.5	-81.2
HWY 41 (SITE 12)	00AL05FE0400	-0.8	28.8	-6.6	-6.6	-37.5	3.0	10.5	5.1	-2.2	-20.7	-6.8	12.1	-6.4	27.0	-27.1	2.5	87.8
HWY 897 (SITE 13)	00AL05FE0850	20.6	-14.3	22.0	23.5	57.0	39.7	27.9	10.9	-7.8	21.8	27.2	42.3	16.1	62.4	52.9	62.1	4.1
UNWIN (SITE 14)	00SA05FE1000	4.5	61.7	13.3	9.1	55.8	29.3	26.2	0.6	7.8	-3.5	19.0	12.2	-1.2	-21.2	64.3	23.5	7.2
HWY 40 (SITE 15)	00SA05FF1000 00SA05FF1000	3.5	-61.0	7.4	14.2	5.3	22.2	19.3	53.9	-20.2	-8.6	20.2	31.5	16.9	-46.1	-33.6	23.9	-46.3
B. MAINSTEM SITES (APRIL 1990 - OCTOBER 1990)																		
HWY 611 (SITE 1)	00AL05FA0250	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
HWY 53 (SITE 2)	00AL05FA0280	73.8	73.3	153.7	20.7	85.7	223.8	757.8	4795.3	939.7	190.3	43.0	219.0	-6.4	525.4	109.0	51.4	
HWY 2A (SITE 3)	00AL05FA0413	55.1	74.7	47.2	30.5	48.0	93.8	140.4	201.5	327.8	31.5	37.4	88.1	147.6	3.2	-70.4	10.5	-53.7
D/S SAMSON L. (SITE 4)	00AL05FA0500	-23.6	-28.4	-20.8	59.3	-11.2	-42.3	-44.1	-34.6	-67.1	-19.3	46.3	-32.2	111.6	11.2	-82.6	-42.6	76.9
HWY 21 (SITE 5)	00AL05FA0700	81.3	62.8	81.1	111.0	164.6	114.3	105.5	44.7	20.6	92.8	115.4	71.1	108.1	32.5	1327.5	391.7	30.2
D/S CAMROSE CR. (SITE 6)	00AL05FA0750	9.5	10.4	11.3	-1.4	33.8	31.6	84.8	84.5	191.8	34.6	4.5	25.8	31.5	7.1	-40.0	-24.9	-4.7
HWY 850 (SITE 7)	00AL05FA1000	-18.8	-0.2	4.8	58.2	-16.7	-1.7	-46.7	-52.5	-57.9	-4.5	41.4	-11.7	27.3	59.4	83.1	-46.6	67.2
U/S FORESTBURG RES. (SITE 8)	00AL05FC0660	0.0	-0.2	0.0	-0.4	-0.2	-0.4	-0.1	-0.5	-37.5	-0.1	-0.3	-0.1	0.0	-0.9	-0.9	-0.3	-0.6
HWY 861 (SITE 9)	00AL05FC0680	25.6	11.5	18.7	-9.8	34.8	40.6	-8.9	270.5	157.1	-1.6	6.9	23.6	-50.1	221.9	392.9	98.5	201.8
HWY 872 (SITE 10)	00AL05FC1000	0.5	-11.5	-6.3	23.6	24.4	15.5	-0.9	-44.5	-33.4	1.6	-18.3	-9.0	-12.2	-57.9	-15.2	23.4	-25.8
D/S HARDISTY (SITE 11)	00AL05FB0500	-8.0	-2.7	-0.8	5.8	-6.9	-11.9	9.6	1.6	-27.7	15.1	7.9	-14.5	6.1	-39.2	172.8	185.8	131.3
HWY 41 (SITE 12)	00AL05FE0400	1.1	4.1	2.2	-3.5	7.8	9.0	3.4	-14.2	-24.1	-14.5	5.1	12.6	-46.0	-61.8	-26.1	10.5	-80.9
HWY 897 (SITE 13)	00AL05FE0850	13.3	9.1	5.5	37.8	55.0	48.4	2.2	3.1	7.0	18.7	29.5	6.7	54.4	-11.8	-49.9	42.5	98.6
UNWIN (SITE 14)	00SA05FE1000	2.9	-1.4	8.2	77.8	32.8	32.0	16.5	24.1	12.5	23.2	41.2	3.8	-0.3	22.2	184.7	53.1	-100.0
C. TRIBUTARIES (APRIL 1990 - OCTOBER 1990)																		
PIGEON L. CR.	00AL05FA0225	13.4	8.7	58.8	27.0	30.7	52.0	124.6	1289.8	244.3	47.1	35.8	61.2	47.6	132.5	28.7	25.6	0.0
WOLF CR.	00AL05FA0287	23.3	24.8	26.3	13.1	123.1	86.0	26.1	66.1	48.5	20.7	16.7	28.0	70.7	20.4	2.4	4.7	7.0
PIPESTONE CR.	00AL05FA0600	71.6	77.3	93.1	48.3	93.3	86.9	93.2	43.3	112.7	85.1	60.0	88.7	61.9	26.1	320.8	184.2	54.6
CAMROSE CR.	00AL05FA0745	6.7	7.6	8.2	4.9	10.5	17.8	59.0	40.7	130.5	12.5	5.6	18.0	10.6	6.4	10.5	4.5	6.7
MEETING CR.	00AL05FC0290	7.8	6.3	6.0	2.4	4.2	4.0	4.7	10.5	8.7	4.0	2.4	5.4	0.8	2.1	3.3	5.6	2.9
BIG KNIFE CR.	00AL05FC0400	0.3	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.3	0.0	0.0	0.4	0.1	0.0
PAINTEARTH CR.	00AL05FC0690	2.8	2.5	2.2	2.0	2.2	2.3	1.6	0.6	1.2	2.1	1.9	1.7	1.3	5.8	4.2	3.3	5.0
CASTOR CR.	00AL05FC0800	1.1	1.1	1.0	0.3	0.2	0.3	0.2	0.0	0.1	0.7	0.3	0.7	0.3	0.3	0.9	0.4	0.0
IRON CR.	00AL05FB0700	9.5	12.8	10.0	3.3	3.7	10.4	2.7	1.3	4.9	6.8	4.4	10.8	5.2	19.9	5.6	3.2	1.3
BUFFALO CR.	00AL05FE0500	0.7	1.4	0.9	0.2	0.1	0.7	0.3	0.1	0.5	0.6	0.1	0.9	0.1	1.2	2.3	0.0	0.0
GRIZZLY BEAR CR.	00AL05FE0600	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
RIBSTONE CR.	00AL05FE0875	3.4	4.4	3.9	0.4	0.4	0.9	1.1	0.2	0.9	2.2	0.5	3.2	0.7	6.3	5.4	0.9	2.3
BLACKFOOT CR.	00AL05FE0890	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.1	0.0	0.0

Table 11. Increment in mass load expressed as percent of upstream (site 1) load. (continued).

STATION	CODE	AS TOT. 33005L	AS DIS. 33102L	BA TOT. 56009L	BA DISS. 56109L	CD TOT. 48009L	CO TOT. 27009L	CR TOT. 24009L	CU TOT. 29009L	MO TOT. 42009L	MN TOT. 25004L	NI TOT. 28009L	FE TOT. 26009L	FE DISS. 26109L	ZN TOT. 30009L	V TOT. 23009L	SE TOT. 34005L
A. MAINSTEM SITES (MAY 1989 - APRIL 1990)																	
BATTLE RIVER AT:																	
HWY 611 (SITE 1)	00AL05FA0250	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
HWY 53 (SITE 2)	00AL05FA0280	162.6	30.5	110.0	87.8	274.7	274.7	60.6	399.6	145.0	38.1	190.4	250.7	159.3	134.2	181.0	274.7
HWY 2A (SITE 3)	00AL05FA0413	33.9	38.4	27.7	39.4	33.9	-33.1	41.3	8.8	18.1	52.1	46.8	4.3	55.8	20.5	9.5	33.9
D/S SAMSON L. (SITE 4)	00AL05FA0500	2.5	-0.2	-19.7	-24.6	-39.7	-3.5	-34.0	-33.2	-3.5	-22.9	-23.4	-28.7	-25.2	7.2	-7.1	-3.5
HWY 21 (SITE 5)	00AL05FA0700	90.3	56.9	101.3	123.5	167.5	420.2	174.4	296.3	137.8	321.5	180.7	519.5	92.2	182.4	157.2	122.9
D/S CAMROSE CR. (SITE 6)	00AL05FA0750	14.0	0.4	1.5	-17.8	15.6	4.1	8.4	8.4	-8.9	4.9	0.0	0.3	10.3	16.9	6.4	4.1
HWY 850 (SITE 7)	00AL05FA1000	-11.1	22.6	-4.4	18.8	-10.5	-29.0	-16.5	-32.4	-0.5	19.2	-10.7	-44.4	-61.4	-34.7	-17.8	861.4
U/S FORESTBURG RES. (SITE 8)	00AL05FC0660	45.4	33.2	21.3	37.8	-7.8	34.9	3.8	77.0	8.7	-12.6	22.6	-6.5	13.7	28.5	3.8	-85.7
HWY 861 (SITE 9)	00AL05FC0680	6.8	-36.6	23.9	53.8	54.3	46.7	103.0	70.2	37.7	15.8	76.9	174.4	170.6	83.4	53.5	-15.9
HWY 872 (SITE 10)	00AL05FC1000	-5.9	-10.0	-3.7	-21.2	16.3	33.2	-22.3	7.4	2.1	-2.8	-5.2	26.3	20.1	40.1	13.6	64.0
D/S HARDISTY (SITE 11)	00AL05FB0500	10.7	17.0	5.8	-16.1	4.5	-4.6	11.4	-8.6	-3.0	19.4	4.5	-3.5	-65.9	-20.6	2.7	-37.3
HWY 41 (SITE 12)	00AL05FE0400	0.8	1.4	6.2	14.3	15.6	14.5	0.2	-2.2	7.9	-5.8	-7.4	3.5	47.2	-3.1	0.2	67.0
HWY 897 (SITE 13)	00AL05FE0850	31.5	-6.1	21.1	12.2	8.0	20.5	30.2	41.1	28.1	32.0	31.6	62.4	56.0	44.3	41.2	38.9
UNWIN (SITE 14)	00SA05FE1000	13.5	0.8	12.9	-12.2	11.8	21.0	10.1	14.8	1.0	11.1	19.4	23.8	8.3	21.3	23.2	4.3
HWY 40 (SITE 15)	00SA05FF1000	27.2	46.4	23.6	22.2	20.8	33.3	55.7	27.4	57.0	30.5	23.3	43.7	15.5	37.6	40.7	0.7
	00SA05FF1000																
B. MAINSTEM SITES (APRIL 1990 - OCTOBER 1990)																	
HWY 611 (SITE 1)	00AL05FA0250	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
HWY 53 (SITE 2)	00AL05FA0280	65.2	111.8	33.3	38.9	159.9	-13.4	8.3	30.0	159.9	123.7	62.5	-1.5	217.2	-2.5	21.3	159.9
HWY 2A (SITE 3)	00AL05FA0413	41.0	67.1	32.5	31.4	15.6	38.8	66.5	61.9	-30.6	46.0	57.3	11.1	55.4	7.9	28.8	85.0
D/S SAMSON L. (SITE 4)	00AL05FA0500	-36.7	-41.3	-37.1	-38.2	-18.8	-66.2	-43.6	-51.7	-32.4	-49.3	-36.3	-47.0	-51.3	-56.5	-32.4	-83.1
HWY 21 (SITE 5)	00AL05FA0700	136.5	107.6	84.6	81.5	73.6	1115.3	160.4	455.6	305.1	474.9	247.2	427.6	321.0	478.7	167.1	420.8
D/S CAMROSE CR. (SITE 6)	00AL05FA0750	13.7	-13.5	23.0	7.7	23.3	35.9	33.9	-7.5	51.0	-23.1	-20.7	29.2	-34.1	51.5	37.4	40.9
HWY 850 (SITE 7)	00AL05FA1000	-14.0	25.0	-6.7	-5.1	-6.2	-6.2	57.9	0.5	3.1	1.5	28.9	-51.0	-65.3	-23.7	-24.3	-6.2
U/S FORESTBURG RES. (SITE 8)	00AL05FC0660	0.2	-0.1	0.0	0.4	0.0	-0.1	-0.6	-0.1	-0.5	0.1	-0.1	0.0	0.0	-0.3	0.0	0.0
HWY 861 (SITE 9)	00AL05FC0680	67.3	40.4	36.9	40.9	34.1	32.0	53.5	116.7	228.6	7.1	38.3	174.6	310.3	159.2	64.3	105.4
HWY 872 (SITE 10)	00AL05FC1000	18.0	-22.2	12.3	-8.1	-1.1	53.8	4.7	23.6	-1.1	15.3	25.8	53.1	45.0	43.6	27.1	13.0
D/S HARDISTY (SITE 11)	00AL05FB0500	-6.2	-2.1	7.4	-9.7	-6.6	6.8	18.6	-0.4	14.4	6.6	14.4	-0.4	-64.9	-11.3	3.8	-46.6
HWY 41 (SITE 12)	00AL05FE0400	15.2	1.4	7.2	12.8	6.2	-1.4	-4.4	-1.4	-0.9	2.8	-5.6	8.5	64.0	16.2	-9.0	112.4
HWY 897 (SITE 13)	00AL05FE0850	36.5	29.0	21.0	23.7	52.8	39.9	24.8	31.6	37.5	36.5	44.4	55.9	71.1	29.9	42.6	20.3
UNWIN (SITE 14)	00SA05FE1000	30.0	-0.1	11.4	-10.2	5.4	11.6	40.6	25.2	-0.4	20.1	15.2	29.0	29.5	41.4	26.5	5.4
C. TRIBUTARIES (APRIL 1990 - OCTOBER 1990)																	
PIGEON L. CR.	00AL05FA0225	31.8	39.1	26.7	29.0	29.3	0.0	22.0	19.5	48.9	63.6	24.4	12.0	56.5	13.4	17.6	97.7
WOLF CR.	00AL05FA0287	45.0	50.8	21.3	21.4	24.2	27.3	27.3	24.2	21.2	35.1	24.2	8.9	18.1	10.1	22.1	18.2
PIPESTONE CR.	00AL05FA0600	94.8	62.8	86.5	73.7	80.2	549.9	116.9	178.7	160.4	160.6	111.7	255.3	97.6	275.0	132.2	275.0
CAMROSE CR.	00AL05FA0745	10.3	9.8	4.0	3.5	9.5	9.8	8.4	6.4	9.0	7.2	6.6	5.9	2.6	12.2	8.9	17.1
MEETING CR.	00AL05FC0290	7.5	5.3	5.9	8.5	5.6	6.8	3.0	9.0	8.1	5.1	6.5	9.2	28.2	8.0	7.2	9.8
BIG KNIFE CR.	00AL05FC0400	0.2	0.1	0.5	0.5	0.1	0.3	0.1	0.2	0.2	0.2	0.3	0.2	0.2	0.1	0.2	0.6
PAINTEARTH CR.	00AL05FC0690	2.7	1.8	2.5	2.4	1.2	2.9	2.1	2.5	2.5	3.6	3.3	3.6	7.6	3.4	2.6	3.2
CASTOR CR.	00AL05FC0800	0.6	0.8	0.8	0.6	1.2	1.1	0.9	0.8	1.0	1.5	0.9	0.3	0.3	0.2	0.9	0.7
IRON CR.	00AL05FB0700	9.2	24.8	2.6	3.9	13.8	4.2	6.2	2.3	5.0	3.8	3.8	1.4	11.8	2.2	4.8	2.7
BUFFALO CR.	00AL05FE0500	0.6	1.9	0.3	0.3	1.5	0.4	1.0	0.2	0.4	0.2	0.6	0.1	0.5	0.0	0.8	0.2
GRIZZLY BEAR CR.	00AL05FE0600	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RIBSTONE CR.	00AL05FE0875	1.5	4.3	1.8	2.1	3.1	0.9	2.0	0.7	1.0	0.6	1.1	0.3	1.7	0.4	1.3	0.6
BLACKFOOT CR.	00AL05FE0890	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Mass loads of most constituents were generally higher in 1990, when samples were taken at higher river flows. However, differences for several major ions or related variables were rather small, because the relationship with flow is inverse. For some constituents, such as sodium, chloride and TDS, mass loads were greater at the lower flows in 1989.

Tributaries to the upper Battle River account for a large portion of the increase in mass load for most constituents (Table 11). Wolf Creek, Camrose Creek and Pipestone Creek, in particular, contribute a considerable percentage of the nutrient load (i.e., carbon, nitrogen and phosphorus) carried by the Battle River. Pigeon Lake Creek contributed greatly to the nitrogen load (mainly $(NO_2^-+NO_3^-)$-N and NH_4^+-N) of the Battle River. Of the lower Battle River tributaries, Meeting, Iron and Ribstone creeks were the most important sources of materials. Their combined contribution was absolutely and relatively less important than that of tributaries upstream of Driedmeat Lake.

Mass transport is discussed further in following sections of this report.

4.1.3.2 Mass Loads from Municipal Discharges in the Basin

Mass loads for selected constituents were calculated for municipalities with licensed discharges. The selection of these constituents was primarily determined by the availability of data. Mass loads were calculated from effluent volume data provided by the municipalities, from average constituent concentrations in samples collected by municipalities in 1989 and 1990 as part of their licence requirements, or from average concentrations of samples collected by the Municipal Branch, Alberta Environment (Standards and Approvals Division 1988). When actual sample data were not available, estimates were derived from Beier (1987). Actual data are presented in Appendix 8. Mass loads are summarized in Table 12.

Considering only those municipalities which discharge to the drainage basin (i.e., excluding municipalities which discharge to landlocked areas), the total annual load from municipal discharge amounts to 41,000 kg total phosphorus, 114,000 kg ammonia nitrogen, 146,000 kg BOD, 257,000 kg NFR, 2,662,000 kg sodium, and 905,000 kg chloride.

4.1.3.2.1 Comparison of Municipal Loads and In-Stream Loads

Average daily effluent loads during the discharge period were derived from Table 12 and expressed as a percent of the average daily load during the open-water season (April to October 1990; Appendix 7) at the nearest upstream Site in the Battle River (Table 13).

Table 12. Annual loads (kg per year) for selected municipal effluent quality characteristics (1989-1990).

MUNICIPALITY	POPULATION	DISCHARGE ROUTE	EFFLUENT VOLUME (m^3/yr)	TP	N-NH_3	BOD	NFR	Na	Cl
Mulhurst	165	Ditch → Pipestone Creek	156 000	374	437	1 248	3 432	21 840	624
Lacombe	6 080	Wolf Creek	766 088	3 890	9 025	35 396	22 573	329 417	61 287
Ponoka	5 473	Battle River	1 572 262	8 097	19 103	13 364	47 953	334 891	73 896
Wetaskiwin	10 103	Town Creek & Pipestone Crk	1 407 778	13 109	55 787	46 310	68 713	249 177	108 399
Millet	1 540	Pipestone Creek	40 000	96	112	320	880	12 680	1 480
Gwynne	97	Pipestone Creek	16 400	39	46	131	361	-	-
Ferintosh	125	Meeting Creek	-	-	-	-	-	-	-
New Norway	278	Ditch → Battle River	32 850	135	348	854	1 117	-	-
Bittern Lake (1)	153	Bittern Lake	3 436	8	10	26	110	2 769	361
Hay Lakes	294	Ditch → Camrose Creek	57 617	138	161	346	45 715	26 043	4 379
Camrose	12 968	Camrose Creek	1 950 716	8 545	18 844	19 701	21 137	464 270	275 050
Ohaton	111	Creek	-	-	-	-	-	-	-
Edberg	124	Creek	9 090	22	25	218	691	3 163	518
Stettler	5 147	Red Willow Creek	632 603	3 202	7 404	20 031	22 595	-	-
Botha	176	Creek	14 914	36	42	507	209	-	-
Donalda	237	Meeting Creek	16 000	38	45	69	83	-	-
Rosalind	214	Driedmeat Creek	-	-	-	-	-	-	-
Bawlf	375	Driedmeat Lake	32 850	79	92	263	723	30 222	4 599
Daysland	678	Driedmeat Creek	136 350	327	382	545	2 318	111 807	20 453
Halkirk	155	Paintearth Creek	-	-	-	-	-	-	-
Heisler (1)	209	Slough	2 220	5	6	18	49	1 043	111
Strome (1)	267	Ditch → Wavy Lake	44 435	107	124	222	978	-	-
Viking (1)	1 160	Thomas Lake	4 812	12	13	103	106	2 257	710
Killam	1 032	Creek/Ditch → Battle River	99 280	238	278	794	2 184	47 158	27 302
Forestburg	936	Creek → Battle River	21 647	52	61	216	87	12 555	6 408
Galahad	176	Slough → Battle River	35 885	86	100	287	789	22 715	19 737
Castor	1 030	Castor Creek	154 030	370	431	462	1 540	-	-
Alliance	202	Creek → Battle River	28 000	145	340	686	882	5 936	1 064
Lougheed	268	Iron Creek	70 080	287	742	1 191	2 383	47 584	19 273
Irma	484	Grattan Creek	91 640	220	257	275	275	46 278	5 957
Coronation	1 310	Ribstone Creek	117 442	537	1 133	5 125	3 117	18 321	19 965
Wainwright	4 665+	Bushy Head Lake → Battle R.	1 040 688	2 050	1 249	3 122	10 407	878 340	254 969
TOTAL (1)			6 329 028	41 322	113 805	146 061	256 772	2 662 397	905 360

(1) Loads from municipalities which discharge to lakes of sloughs without direct drainage to the Battle River or its tributaries are not included
Refer to Appendix 8 for data and data sources

Table 13. Average daily municipal load[1] of selected constituents expressed as a percent of the average daily load[2] in the receiving tributary or at the first Battle River site upstream of the discharge.

MUNICIPALITY	DISCHARGE PERIOD[3] (No. days/year)	CONSTITUENT				
		TP	CHLORIDE	SODIUM	BOD	NH_3-N
Lacombe	28	154	170	96	61	537
Ponoka	13	799	192	161	33	9184
Mulhurst	70	108	46	22	26	555
Millet						
Gwynne						
Wetaskiwin						
Camrose	43	91	95	31	9	266
Stettler	33	35	NA	NA	10	138
Donalda						
Castor	1	155	NA	NA	9	248
Lougheed	1	119	171	82	25	511
Wainwright	365	2	6	4	0	2
Coronation	1	137	149	22	114	741

(1) Average applies to period of discharge, only
(2) Average applies to open-water period (April-October 1990)
(3) Refer to Figure 2 for timing of discharge
NA = No data available

During their wastewater discharges, municipalities increase local river loads of TP by 2 to 799%, of Cl by 6 to 192%, of Na by 4 to 161%, of BOD by 0 to 114% and of ammonia by 2 to 9184%.

The percentages shown in Table 13 are a function of the quality of the effluent for the various municipalities, but also of background loads in the river and of the duration of the discharge of wastewater. Direct comparisons of relative contributions among municipalities are therefore not valid.

The apparently low contributions of materials by the town of Wainwright to the Battle River deserve further explanation. Wainwright presently discharges its effluent to a saline lake, Bushy Head Lake, which effectively continues the treatment of the effluent. Water pumped from the lake to the Battle River contains less TP, BOD, and NH_3-N than the treated effluent discharged to the lake. In addition, daily loads to the river are smaller than for other municipalities because Wainwright discharges continuously rather than during a relatively short period of time in spring and fall. Because Bushy Head Lake is saline, Wainwright discharges rather large amounts of Cl and Na to the Battle River. This is not reflected in figures shown in Table 13 because discharges are continuous and because background levels of these ions in the Battle River are high.

4.1.3.2.2 Comparison of Municipal Loads and Mass Loads at Unwin

Because chemical, physical and biological processes can greatly alter concentrations of non-conservative constituents, in-stream loads for these variables may bear little relationship to effluent loads. For this reason, the conservative elements sodium and chloride are considered here. Total phosphorus is included also, even though it does not behave truly conservatively.

Monthly TP, sodium and chloride loads were calculated for the federal long-term Unwin site for the last 10 years. Average monthly flows were multiplied by the concentration record and the number of days in that month. Annual loads were derived from the sum of monthly loads from January to December. In Table 14 these river loads are compared to loads from municipalities as described in Table 12.

From 1980 to 1990 at Unwin, municipal discharges accounted for an average of 67%, 16% and 34% of the annual TP, Na and Cl loads, respectively.

There is a strong positive relationship between the mean annual flow and the annual TP load at Unwin. In low flow years, the TP load from municipal discharges greatly exceeds the annual TP load at Unwin. This suggests that a considerable portion of the TP discharged by municipalities in the basin gets trapped in biomass and sediments of the Battle River, its tributaries and on-stream lakes. In high flow years, the annual TP load at Unwin is larger than the load contributed by municipalities. Under high flow

Table 14. Comparison of annual mass load of conservative constituents at Unwin with annual mass loads from municipal discharges.

ANNUAL MASS LOAD AT UNWIN				
	MEAN ANNUAL DISCHARGE m^3/s	ANNUAL MASS LOAD (kg/yr)		
		TP	SODIUM	CHLORIDE
1980	7.35	54 040	17 366 285	2 162 312
1981	6.66	33 617	14 747 527	2 625 410
1982	12.4	148 133	19 549 594	3 004 614
1983	11.4	116 140	24 199 337	3 375 401
1984	3.3	12 443	10 937 999	1 791 964
1985	9.03	85 029	13 538 876	1 820 250
1986	8.31	53 774	19 688 908	3 151 951
1987	6.82	46 782	16 864 903	2 838 526
1988	2.02	4 894	7 999 730	1 367 817
1989	2.1	16 832	12 695 381	2 690 409
1990 (1)	17.6	105 151	24 310 900	4 246 866
AVERAGE		61 531	16 536 313	26 432 289
ANNUAL MUNICIPAL LOAD (2)				
- in kg/year		41 322	2 662 397	905 360
- as % of Unwin load mean (min-max)		67 (28-844)	16 (11-33)	34 (21-66)

(1) Incomplete year (data from January to September)
(2) Refer to Table 12

conditions, much of the TP immobilized and accumulated during dry years travels downstream. Concurrently, the expected TP contribution from surface runoff would be higher in wet years.

Total annual sodium and chloride loads at Unwin are less dependent on flows than TP loads; consequently they vary less from year to year. From 1980 to 1990 the contribution of municipal effluents to the total annual sodium and chloride load at Unwin ranged from 11 to 33% and from 21 to 66%, respectively.

4.2 SHORT-TERM EFFECTS OF WASTEWATER DISCHARGES ON RIVER WATER QUALITY - PONOKA CASE STUDY

4.2.1 Introduction

The surveys conducted during the municipal wastewater discharges from the Ponoka municipal wastewater treatment plant to the Battle River document the changes which occur in the river's quality during the passage of the plume. These are short-term, localized, acute changes rather than long-term, more wide-spread, chronic changes. The latter changes are more characteristic of general river water quality and are discussed in sections below.

The wastewater stabilization ponds operated by the town of Ponoka consist of four anaerobic cells, one facultative cell, and three storage cells. This type of lagoon configuration generally produces an effluent of better quality than that from configurations with fewer cells (e.g., Beier 1987). Discharge of wastewater stabilization pond effluent occurs twice a year (spring and fall) through the lower storage cell. Compared to other municipalities in the Battle River basin, Ponoka's wastewater effluent is of average to above average quality (e.g., Standards and Approvals Division 1988). The 1990 discharges occurred from May 14 to May 22 and from September 17 to September 24; the total volume per discharge was 786,131 m^3 (pers. comm. G. Hohlmen, Town of Ponoka 1991). This corresponds to a discharge rate of approximately 1 m^3/s.

Changes in river water quality during the discharge of wastewater effluent are a function of the effluent quality and of the dilution capacity of the receiving stream. In 1990 Battle River flows were higher than average (see Figure 4) during both the spring and the fall discharge. Changes in river water quality as a result of effluent discharge would be more pronounced in low flow years. Average river flows at Ponoka were 4.1 m^3/s and 1.6 m^3/s during the spring and fall discharge, respectively. Half-way through the spring discharge, river flows increased by more than 1 m^3/s (Appendix 2), which contributed even more to the dilution of effluent. All other large municipalities in the Battle River basin discharge to creeks which have a smaller dilution capacity than the Battle River at Ponoka. For a similar level of effluent quality,

discharges from these municipalities would induce larger changes in creek water quality than those described below for the Battle River.

4.2.2 Results and Discussion

Selected survey data are summarized in Figure 5 to 13, and all data are presented in Appendix 3. Datasonde records are shown in Figure 5 to 7. Data from samples collected with ISCO samplers upstream and downstream of the effluent outfall, were tested with the Wilcoxon signed rank test to determine whether pairs of samples taken on the same day differed significantly in water quality characteristics. Results of this test are summarized in Table 15.

In spring, the Ponoka wastewater effluent contained large quantities of algal material which gave the river a bright green colour. Planktonic chlorophyll *a* was not measured during the spring surveys, although the presence of algal activity was reflected in several water quality constituents such as dissolved oxygen, pH and especially total phosphorus and particulate nitrogen and carbon levels.

Discharges in May started a day earlier than scheduled. As a result the first samples downstream of the outfall were taken in the plume, as reflected by the high concentrations recorded for many constituents.

4.2.2.1 Datasonde Records: Dissolved Oxygen, pH, Conductivity

Hourly datasonde records show that pH and dissolved oxygen were slightly higher downstream than upstream of the outfall prior to the effluent discharge (Figures 5 and 6). During the effluent release, differences among sites became more accentuated. Compared to the upstream site, pH and dissolved oxygen at the lower sites rose more during the day, pH declined less and DO declined more at night.

Hourly datasonde records of conductivity indicate that diurnal variability at sites below the outfall was greater than at the site above the outfall. Conductivity increased considerably during the passage of the effluent and served as a tracer of the plume (Figure 7).

4.2.2.2 Major Ions and Related Variables

During the wastewater discharge, concentration of major ions and related variables was higher 4 and 8 km downstream of the effluent outfall than upstream, but there were no concentration differences between the 4 and 8 km sites (Table 15). Although changes followed a similar pattern in spring and fall, concentration increases were larger in fall when the dilution capacity of the river was less. Major ions having the largest relative concentration changes were sodium, chloride, sulphate, bicarbonate, potassium

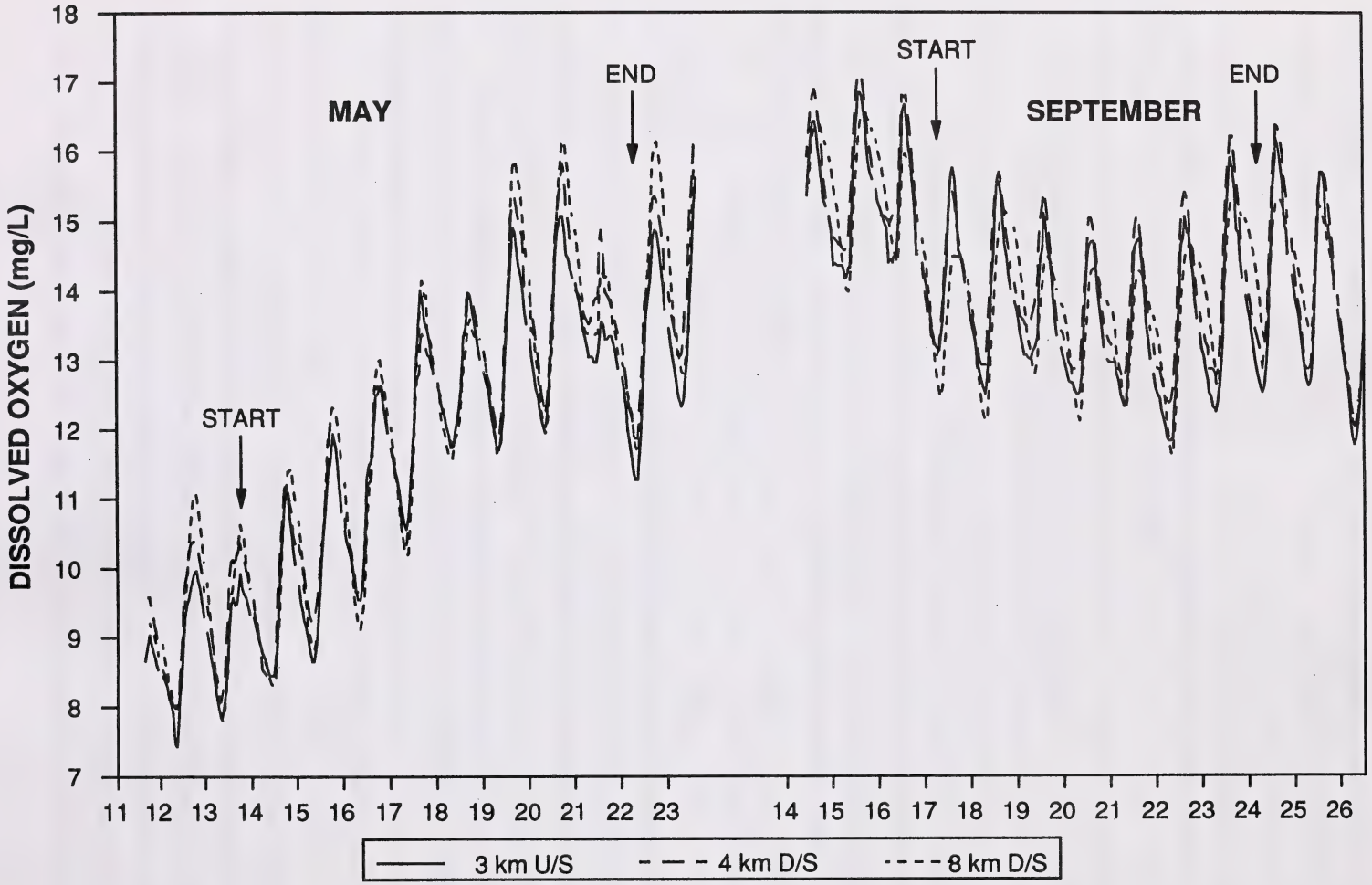


FIGURE 5. DISSOLVED OXYGEN in the Battle River during Ponoka wastewater discharges in spring (May) and fall (September), 1990.

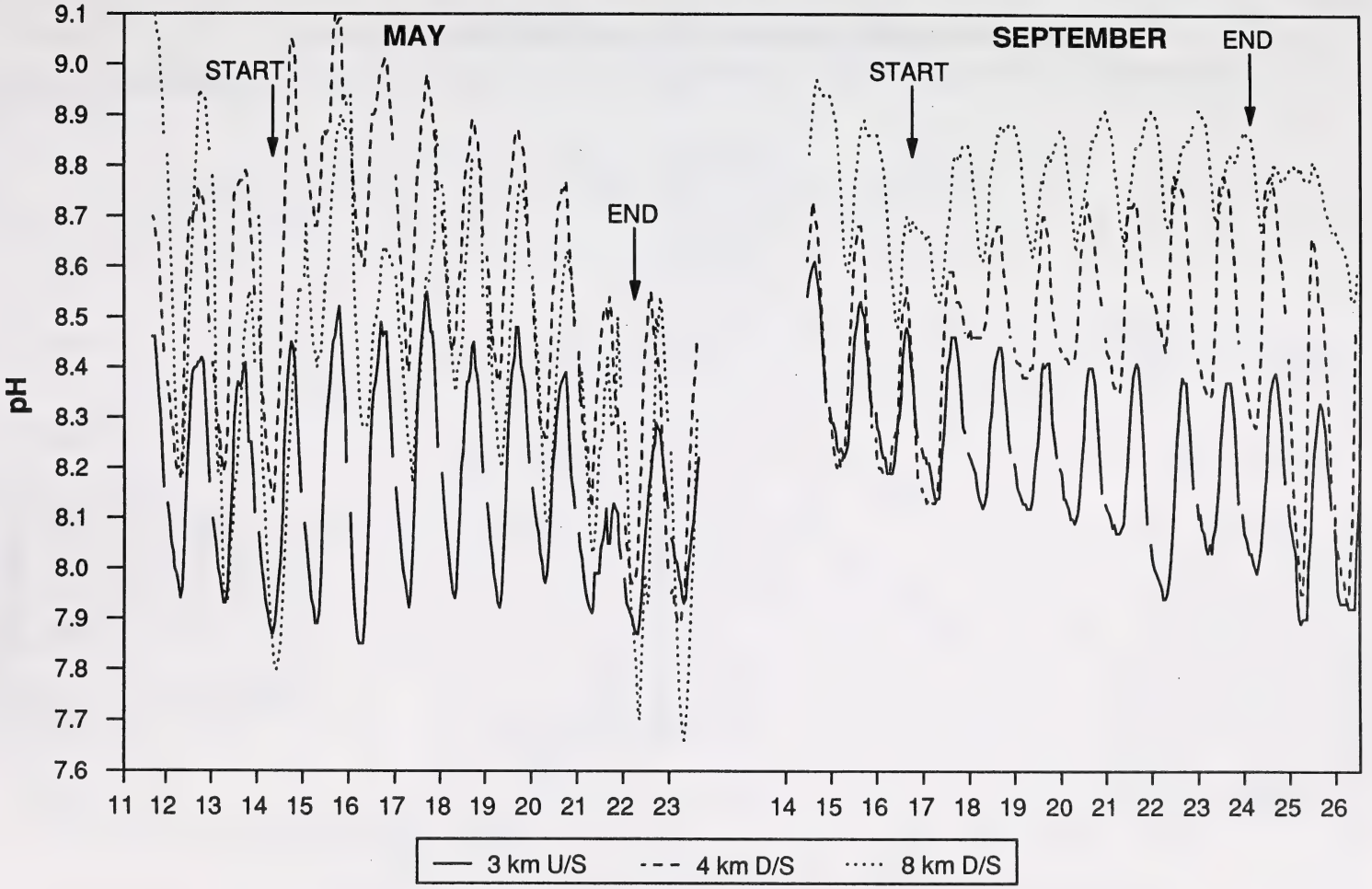


FIGURE 6. pH in the Battle River during Ponoka wastewater discharges in spring (May) and fall (September), 1990.

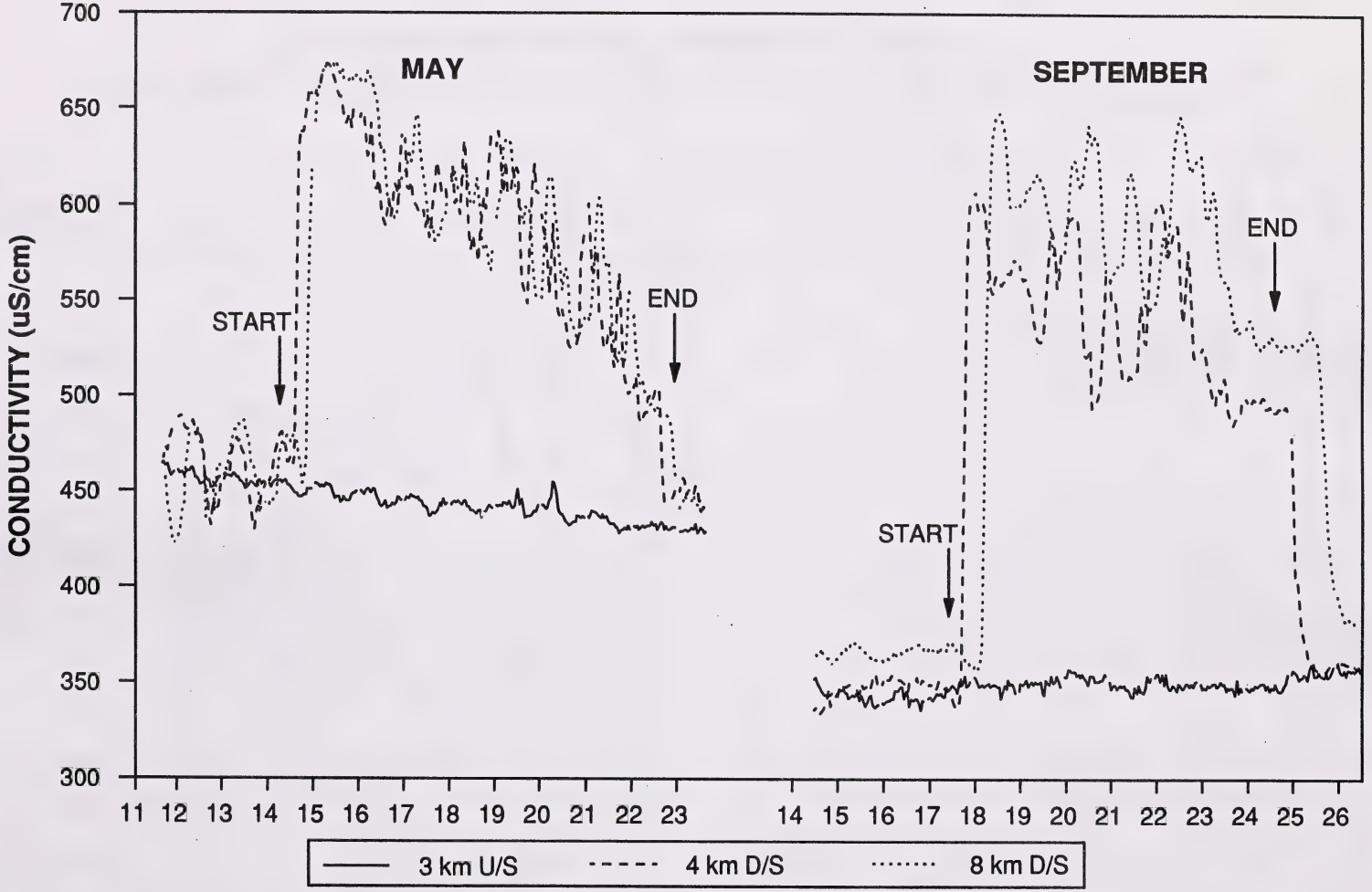


FIGURE 7. CONDUCTIVITY in the Battle River during Ponoka wastewater discharges in spring (May) and fall (September), 1990.

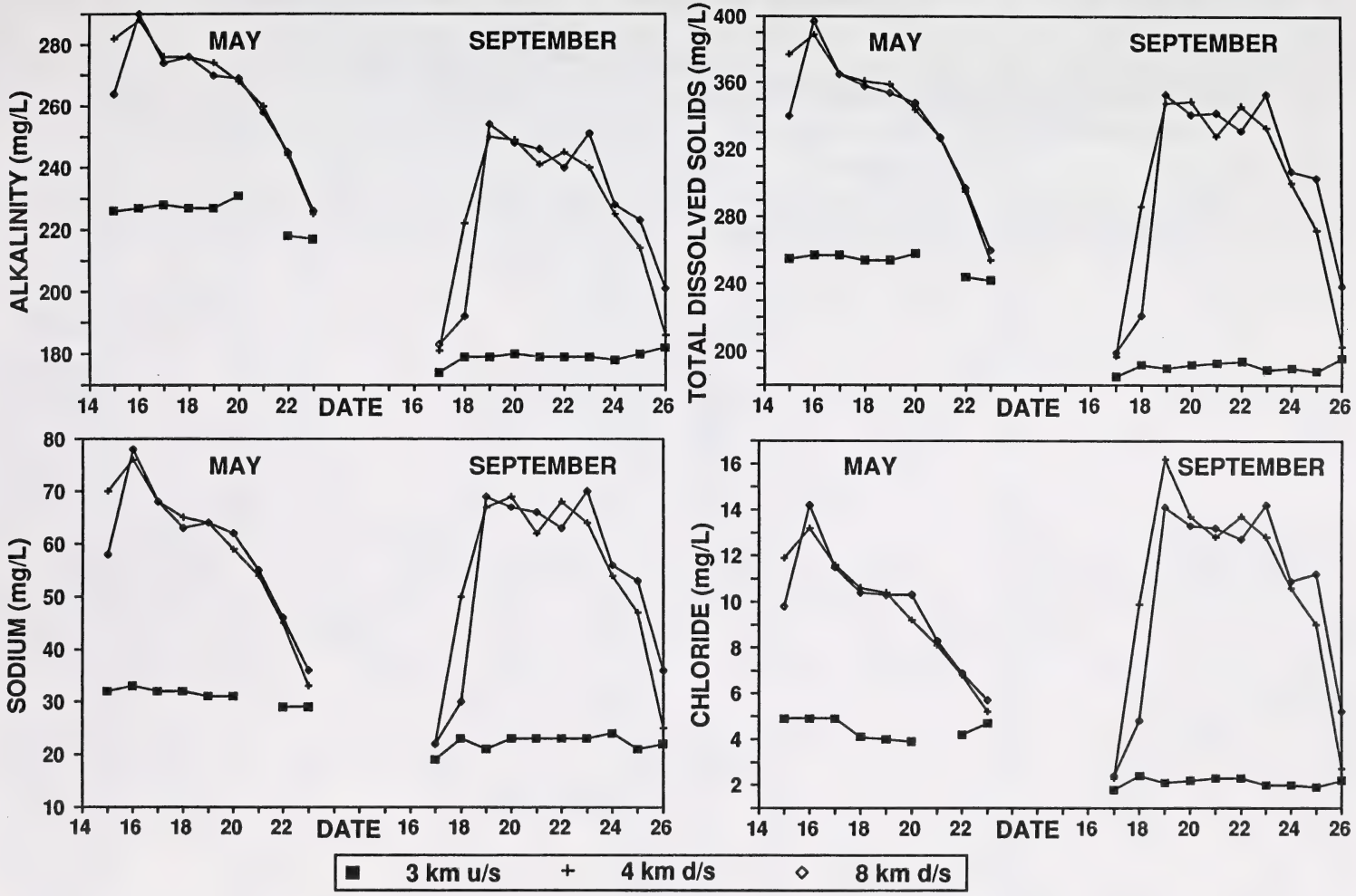


FIGURE 8. ALKALINITY, TOTAL DISSOLVED SOLIDS, SODIUM, AND CHLORIDE in the Battle River during the Ponoka wastewater discharges in spring (May) and fall (September), 1990.

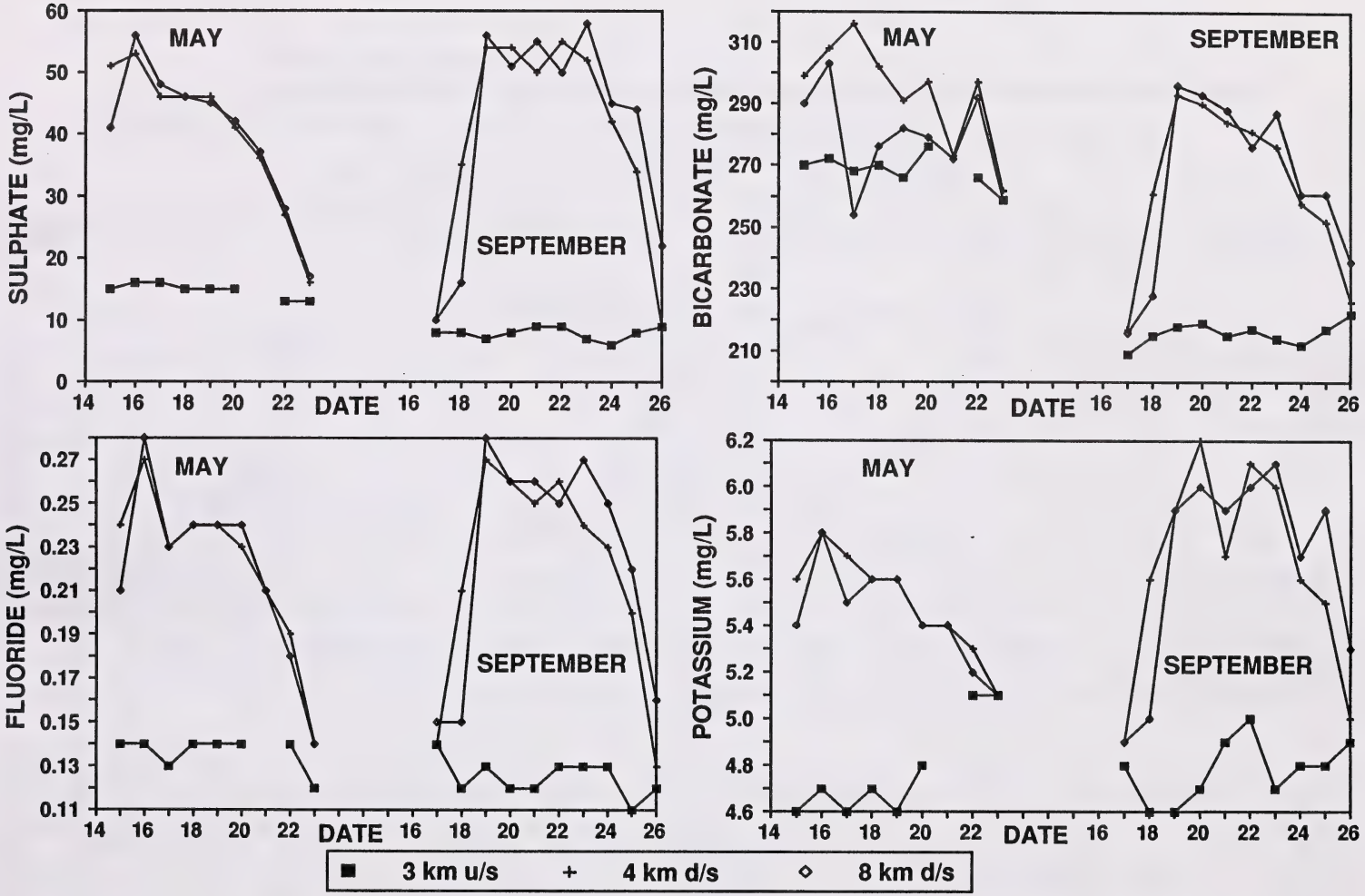


FIGURE 9. SULPHATE, BICARBONATE, FLUORIDE, AND POTASSIUM in the Battle River during the Ponoka wastewater discharges in spring (May) and fall (September), 1990.

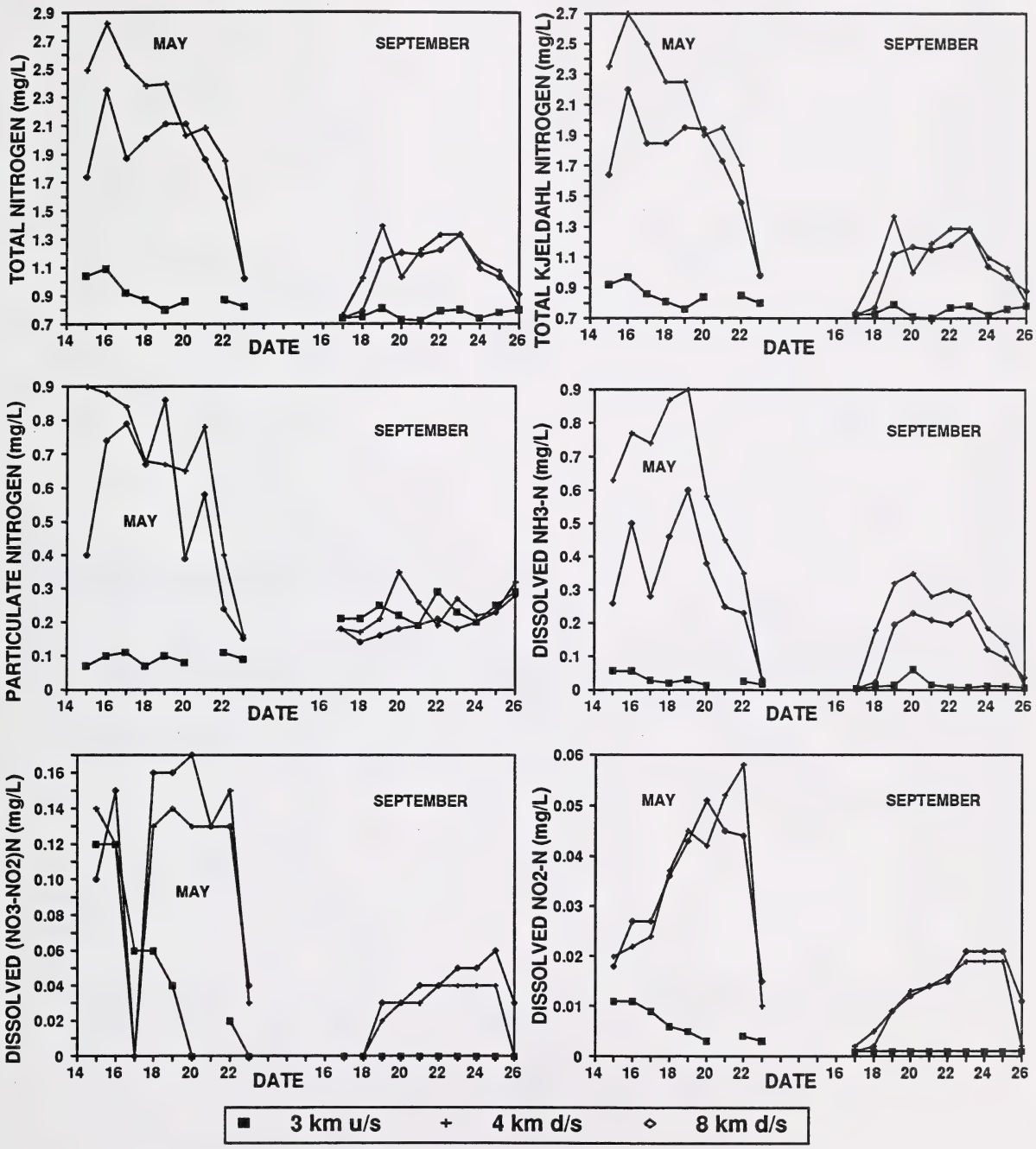


FIGURE 10. TOTAL NITROGEN, TOTAL KJELDAHL NITROGEN, PARTICULATE NITROGEN, AMMONIA NITROGEN, NITRITE+NITRATE NITROGEN, AND NITRITE NITROGEN, in the Battle River during the Ponoka discharges in spring (May) and fall (September), 1990.

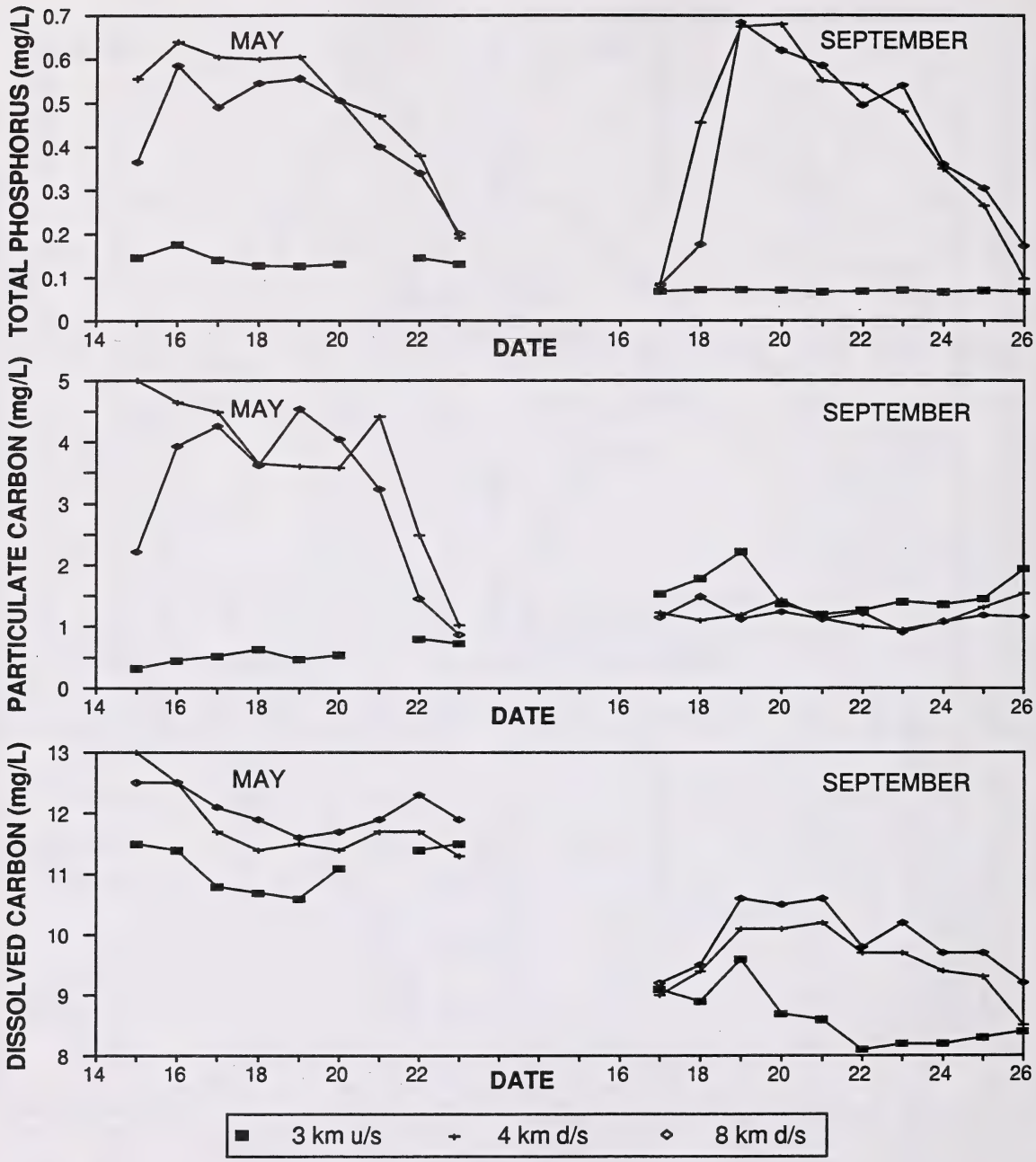


FIGURE 11. TOTAL PHOSPHORUS, PARTICULATE CARBON, AND DISSOLVED ORGANIC CARBON, in the Battle River during the Ponoka wastewater discharges in spring (May) and fall (September), 1990.

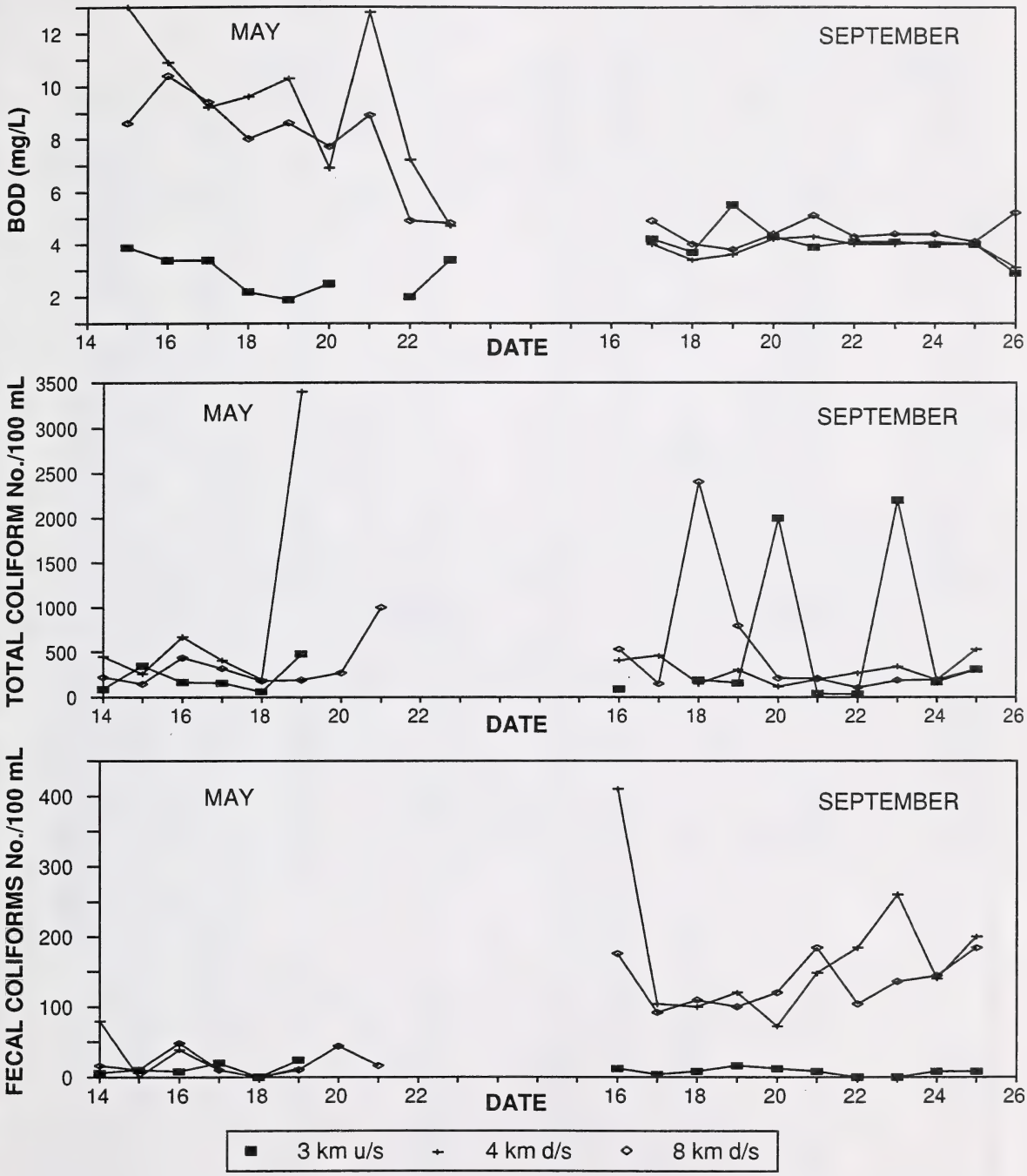


FIGURE 12. BOD, TOTAL COLIFORMS, AND FECAL COLIFORMS in the Battle River during the Ponoka wastewater discharges in spring (May) and fall (September), 1990.

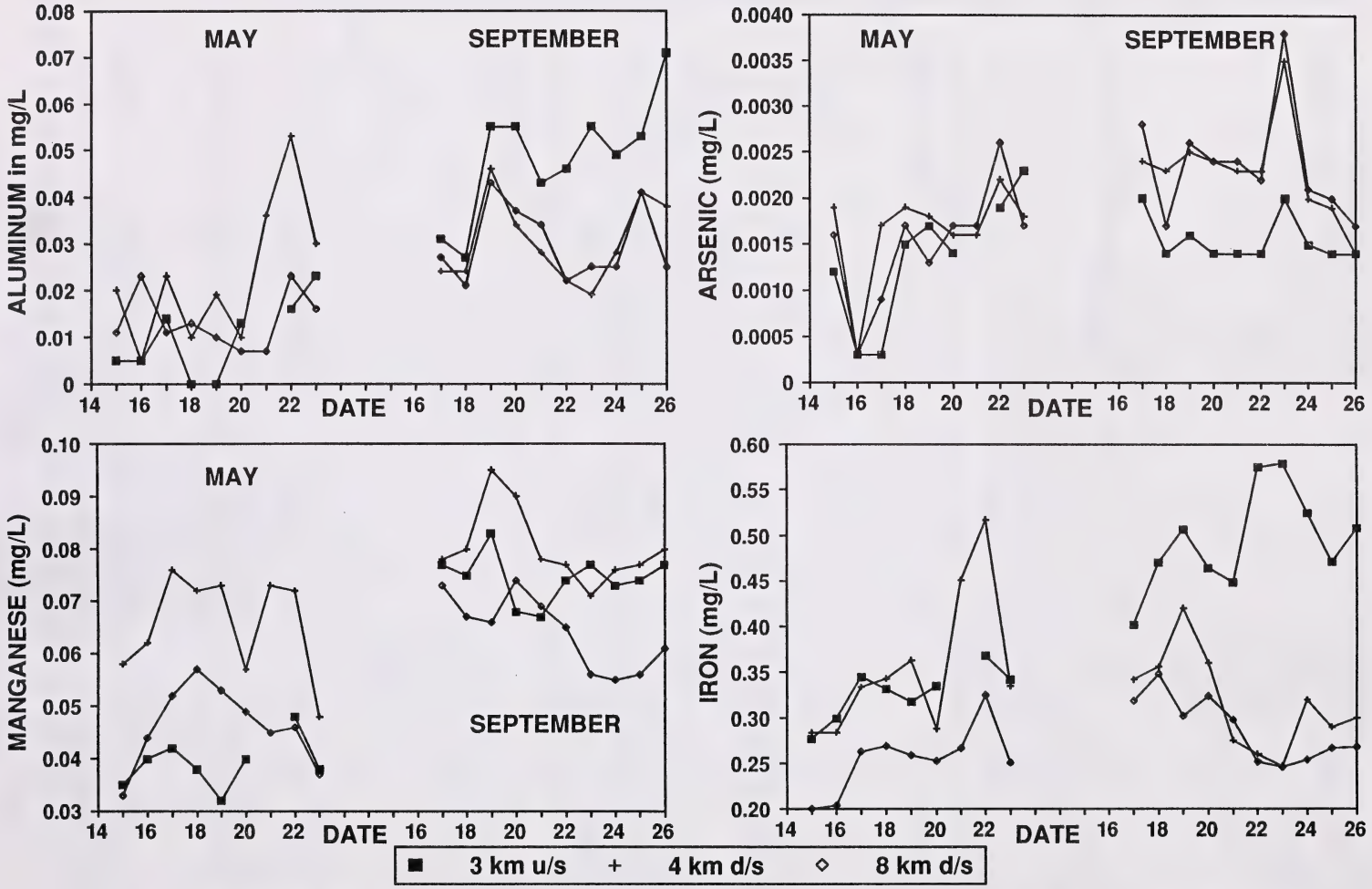


FIGURE 13. ALUMINUM, ARSENIC, MANGANESE, AND IRON in the Battle River during the Ponoka wastewater discharges in spring (May) and fall (September), 1990.

Table 15. Summary of results of Wilcoxon signed rank test comparing water quality characteristics of the Battle River upstream and at two sites downstream of Ponoka municipal discharges.

VARIABLE	SPRING			FALL		
	3 km u/s vs. 4 km d/s	3 km u/s vs. 8 km d/s	4 km d/s vs. 8 km d/s	3 km u/s vs. 4 km d/s	3 km u/s vs. 8 km d/s	4 km d/s vs. 8 km d/s
Temperature	* (+)	* (+)	ns	ns	ns	ns
pH	* (+)	* (+)	ns	* (+)	* (+)	ns
Alkalinity	* (+)	* (+)	ns	* (+)	* (+)	ns
Specific Cond.	* (+)	* (+)	ns	* (+)	* (+)	ns
TDS	* (+)	* (+)	ns	* (+)	* (+)	ns
Calcium	* (+)	ns	ns	* (+)	* (+)	ns
Magnesium	* (+)	* (+)	ns	* (+)	* (+)	ns
Sodium	* (+)	* (+)	ns	* (+)	* (+)	ns
Potassium	* (+)	* (+)	ns	* (+)	* (+)	ns
Bicarbonate	* (+)	ns	* (-)	* (+)	* (+)	ns
Carbonate	* (+)	* (+)	ns	ns (+)	* (+)	ns
Chloride	* (+)	* (+)	ns	* (+)	* (+)	ns
Sulphate	* (+)	* (+)	ns	* (+)	* (+)	ns
Fluoride	* (+)	* (+)	ns	* (+)	* (+)	ns
Silica	ns	ns	* (-)	* (+)	ns	* (-)
DO	* (+)	* (+)	ns	* (-)	* (-)	ns
BOD	* (+)	* (+)	ns	ns	ns	* (+)
NFR	* (+)	* (+)	* (-)	* (-)	* (-)	* (-)
FR	* (+)	* (+)	ns	* (+)	* (+)	ns
Turbidity	* (+)	* (+)	* (-)	* (-)	* (-)	ns
Colour	ns	ns	ns	* (+)	* (+)	ns
DOC	* (+)	* (+)	* (-)	* (+)	* (+)	* (+)
POC	* (+)	* (+)	ns	ns	ns	ns
TP	* (+)	* (+)	* (-)	* (+)	* (+)	ns
$N\text{-}NH_3$	* (+)	* (+)	* (-)	* (+)	* (+)	* (-)
$N\text{-}NO_2+NO_3$	ns	ns	ns			
$N\text{-}NO_2$	* (+)	* (+)	ns	* (+)	* (+)	ns
N-TKN	* (+)	* (+)	* (-)	* (+)	* (+)	ns
N-Particulate	* (+)	* (+)	ns	ns	* (-)	* (-)
N-Total	* (+)	* (+)	* (-)	* (+)	* (+)	ns
Chl *a*	NA	NA	NA	ns	* (-)	* (-)
Coliform Total	ns	ns	ns	ns	ns	ns
Coliform Fecal	ns	ns	ns	* (+)	* (+)	ns
Aluminum	ns	ns	ns	* (-)	* (-)	ns
Arsenic	ns	ns	ns	* (+)	* (+)	ns
Barium	* (-)	* (-)	* (-)	* (-)	* (-)	ns
Cadmium	ns	ns	ns	ns	ns	ns
Chromium	ns	ns	ns	ns	ns	ns
Copper	ns	ns	ns	ns	ns	ns
Manganese	* (+)	ns (+)	ns (-)	* (+)	* (-)	* (-)
Nickel	ns	ns	ns	ns	ns	ns
Iron	ns	* (-)	* (-)	* (-)	* (-)	* (-)
Zinc	ns	ns	ns	ns	ns	ns
Vanadium	ns	ns	ns	ns	ns	ns

* = Significantly different at $P \leq 0.05$ + = Significant increase
- = Significant decrease ns = Not significant at $P \leq 0.05$

and fluoride (Figures 8 and 9). Increases in ionic concentrations were also reflected in increases in total dissolved solids, alkalinity, and conductivity (Figure 8). Despite the overall increase in salt concentration, the total dissolved solids concentration remained well below 500 mg/L which, according to CWQG, makes it suitable for the irrigation of the most sensitive crops. As discussed later (4.2.2.5), bacteria levels may restrict irrigation of some crops.

4.2.2.3 Nutrients

Nitrogen

Most of the increase in total nitrogen (N), levels recorded in May 1990 below the outfall were due to the increase in particulate nitrogen and ammonia-N (Figure 10; Table 15). Although levels of nitrate-N and nitrite-N also increased, they contributed much less to the overall concentration increase (Figure 10). Ammonia-N levels declined between the 4 and 8 km site below the effluent outfall (Table 15) suggesting that ammonia-nitrogen is rapidly oxidized by an in-stream nitrification process. Nevertheless, ammonia-N levels exceeded CWQG for the protection of aquatic life (CCREM 1987) on most sampling days in May and at both sites below the outfall. This suggests that in spring CWQG were exceeded not only within the 8 km river stretch below the outfall, but for an undetermined distance further downstream. CWQG for ammonia-N were not exceeded in the fall survey.

The lower in-stream concentrations of all nitrogen forms during the fall discharges are primarily a result of the better effluent quality in the fall (Beier 1987).

Phosphorus

During the wastewater discharge period, total phosphorus levels were 5 to 7 times higher below than above the effluent outfall (Figure 11, Table 15). Although the AASWQIG of 0.05 mg/L for total phosphorus were exceeded in all river samples below the effluent outfall, they were also exceeded on all occasions upstream of the outfall. Total phosphorus levels in wastewater stabilization ponds with biannual discharges tend to be lower in fall than in spring (Beier 1987). However, river phosphorus levels were as high in fall as in spring because of the lower dilution capacity of the river in fall.

Carbon

During the spring and fall discharges, dissolved organic carbon concentrations were higher at the two sites downstream of the outfall than upstream (Table 15, Figure 11). Particulate carbon was much

higher downstream of the outfall during the spring discharges because of the large quantity of algae in the effluent, but levels were similar at all sites in the fall when algae were not abundant (Table 14).

4.2.2.4 BOD

BOD levels were much higher below than above the effluent outfall during the spring discharge, but there was no difference during the fall discharge (Table 14, Figure 12). At least part of these longitudinal and seasonal differences are attributable to the presence of larger amounts of algae and dissolved organic carbon in the spring effluent.

4.2.2.5 Bacteria

No significant differences were detected in total and fecal coliform levels among the sampling sites in spring (Table 14, Figure 12). CWQG for total coliform levels in irrigation water (i.e., maximum of 1000 total coliforms per 100 ml) were exceeded once during the spring discharge downstream of the effluent outfall, and several times during the fall discharge, above and below the outfall. In fall, fecal coliform levels were consistently higher downstream of the outfall (Figure 12, Table 14). Although counts complied with AASWQIG at the two sites, they exceeded CWQG for irrigation water (i.e., maximum of 100 fecal coliforms per 100 ml). For recreational waters CCREM recommends that the geometric mean of not less than 5 samples taken over a 30 day period be less than 200 fecal coliforms per 100 ml. The geometric mean of fecal coliforms in the Battle River 4 km downstream of the outfall over a 10-day period was 154. There is some question as to the origin of the fecal coliforms recorded downstream of the effluent in this survey, as counts were higher downstream than upstream of the outfall even before the scheduled start of the discharge. The fecal coliforms likely originated from the Ponoka hospital which is the only other known discharge in that reach of the river (see Section 2.1.2).

4.2.2.6 Trace Elements

The concentration of many trace elements (i.e., cadmium, chromium, copper, nickel, zinc, vanadium) did not change significantly downstream of the effluent outfall (Table 14). Some metals such as aluminum (in fall), barium (in spring and fall) and iron (in fall) even decreased in concentration below the effluent outfall (Table 14, Figure 13). Arsenic levels were significantly higher below the outfall in September, but in-stream concentrations complied with CWQG (0.05 mg/L) and AASWQIG (0.01 mg/L) at all times (Table 14, Figure 13).

Manganese levels followed a rather unusual pattern. Concentrations were significantly higher in spring and fall downstream of the outfall at the 4 km site, but they declined significantly by the 8 km site in both seasons (Table 14). In fall, concentrations at the 8 km site were even lower than at the site above the outfall (Table 14, Figure 13). Precipitation of manganese from solution in an oxidizing environment (CCREM 1987) is a possible explanation for this pattern.

Metal such as beryllium, cobalt, lead, mercury, molybdenum and selenium were too often below the analytical detection limit to determine the presence of spatial or temporal changes.

4.2.3 Conclusion

Discharges of Ponoka municipal effluent to the Battle River resulted in elevated river concentrations of major ions, conductivity, total dissolved solids, total phosphorus and dissolved and particulate forms of nitrogen and carbon.

Municipal discharges did not result in an increase of trace metals or other trace elements, except for arsenic and manganese which were slightly elevated below the outfall.

Municipal discharges did not result in a significant increase of total coliforms in spring or in fall. However, CWQG for irrigation water were exceeded on several occasions. Increases of fecal coliforms downstream of Ponoka in fall were probably related to discharges from the Ponoka hospital. Fecal coliform counts exceeded CWQG for irrigation downstream of Ponoka in the fall.

Poorer effluent quality in spring than in fall was reflected in more elevated in-stream spring concentrations of BOD, particulate and dissolved carbon and nitrogen. In-stream concentrations of ammonia-N exceeded CWQG for at least 8 km downstream of the effluent outfall in spring, but concentrations complied with guidelines in fall.

In-stream total phosphorus and major ion concentrations were as high during the discharge in fall as in spring because the river had a lower dilution capacity in the fall.

4.3 SPATIAL AND TEMPORAL CHANGES IN BATTLE RIVER WATER QUALITY

4.3.1 Physical Water Quality Characteristics

4.3.1.1 Temperature

Temperature variations are part of the normal climatic regime and natural bodies of water exhibit both seasonal and diurnal variations. Temperature plays a major controlling role in aquatic environments by influencing biological, physical and chemical processes (CCREM 1987). Discharges

from thermal electricity generating plants are among the most important factors which alter the temperature of receiving water bodies.

Highest temperatures in the Battle River occur during the month of July with an average of 21°C over the period of record (1974-1990) at Unwin (Figure 14). The highest water temperature on record for Unwin was 29°C measured on June 28, 1988, at a time when river flow was unusually low (1.98 m^3/s). The Battle River is ice-covered from November to mid-March and water temperature is at or near 0°C at that time.

Average temperatures for the 1989-1990 surveys increased very gradually in a downstream direction to the Saskatchewan border, but Saskatchewan sites were slightly cooler (Figure 15). The largest increase in average river water temperature occurred in the upper portion of the river (site 1 to site 3) and likely reflects the increase in river size, whereby the surface areas shaded by shoreline vegetation decrease and areas subject to solar radiation increase. Average temperatures recorded in tributaries during the open water season of 1990 also tended to be lower in the upper portion of the basin (Figure 15).

Alberta Power Ltd. uses the Forestburg Reservoir as a source of cooling water; it is by far the largest consumer of water in the basin. Most of the cooling water is returned to the reservoir via discharge to the upper portion of the reservoir. There are no company records documenting the temperature of this water. Records of 1989 indicate that average water temperatures near the reservoir inlet (and near the cooling water outfall) were 6.5°C higher than near the reservoir outlet.

Water Temperature in Forestburg Reservoir (in °C)

		NEAR INLET	NEAR OUTLET
1989	May 30	13.3	18.1
	June 27	22.4	19.4
	July 26	29.9	23.6
	August 24	28.3	21.0
	September 28	28.1	19.9
	October 24	24.5	14.5
1990	January 10	6.5	NA

NA = no data available

Although a temperature gradient was apparent in the reservoir, average temperatures upstream (site 8) and downstream (site 9) of the reservoir were similar (Figure 15). The slow passage of water through the reservoir usually ensures enough time for water temperature to stabilize with air temperatures.

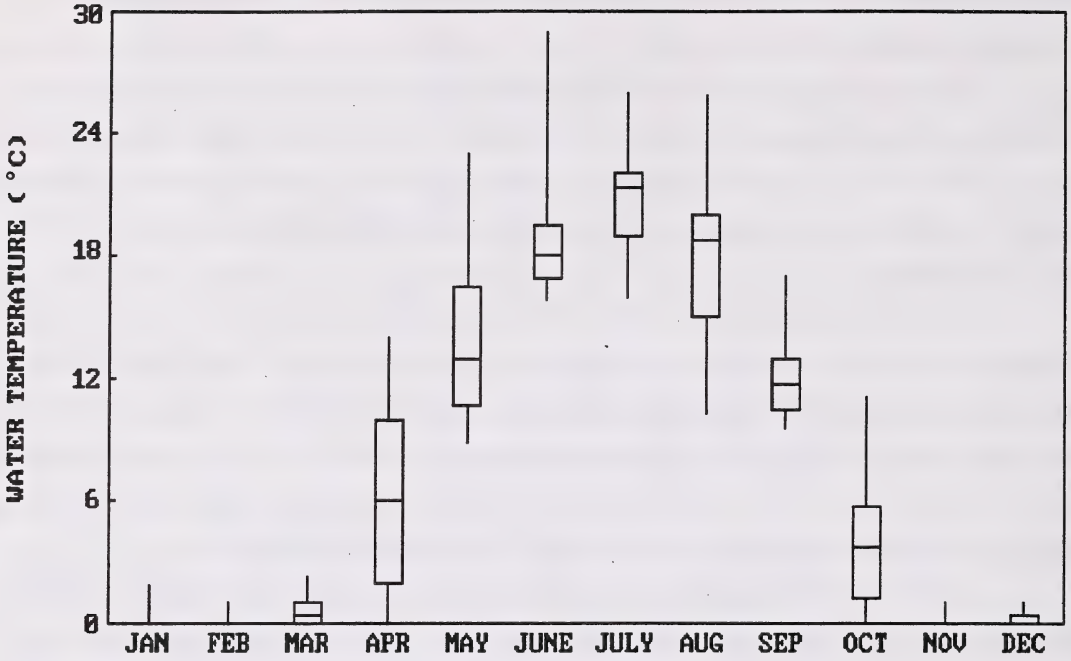


FIGURE 14. TEMPERATURE - SEASONAL CHANGES AT UNWIN (1974-1990).

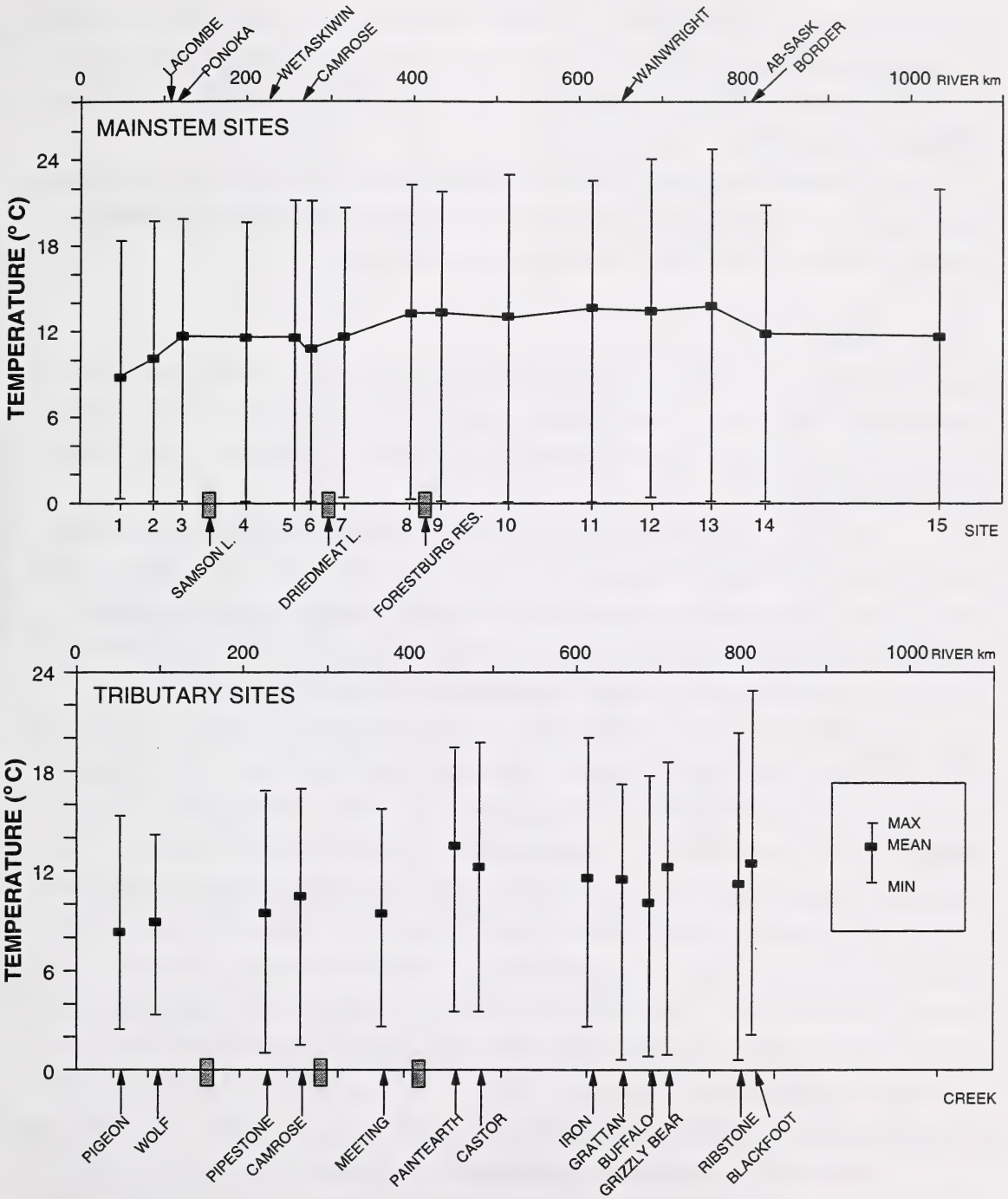


FIGURE 15. TEMPERATURE in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

However, during spring runoff when water flows quickly through the reservoir, river temperatures may be 6°C higher downstream than upstream (site 9) of the reservoir, and the warming effect may be observed as far as 200 km downstream (Figure 16). During the winter an ice free zone is maintained for some distance downstream of the reservoir.

AASWQIG specify that temperature should not be increased by more than 3°C over ambient water temperatures. These objectives are exceeded during periods of high flow downstream of the Forestburg Reservoir; they are probably exceeded at all times in the reservoir.

4.3.1.2 Colour

The true colour of natural waters is the colour of water from which turbidity has been removed (i.e., the colour of filtered water). Natural minerals such as calcium carbonate, ferric hydroxide, organic substances, tannins and lignins and humic acids from decaying vegetation can impart true colour to natural waters (CCREM 1987).

The period of record for true colour at Unwin is fairly short (1981-1990) and this likely accounts for the rather irregular seasonal pattern in this variable (Figure 17). There is only a slight tendency towards higher true colour readings during the open water season. A trend towards a decline in true colour was detected over this short period of record (Table 10, Figure 17). This decline, 1.7 RCU per year, is small compared to the average colour levels in the river and has no obvious explanation.

In 1989-1990 average true colour values ranged from 23 RCU at Highway 611 (site 1) to 49 RCU downstream of Samson Lake (site 4) (Figure 18). High colour values were also recorded downstream of Driedmeat Lake (site 7 and 9) suggesting that both lakes contribute colour to the river. Average total colour downstream of the Forestburg Reservoir (site 9) was lower than upstream and declined steadily to the mouth (site 15). Variability in true colour was higher upstream of Driedmeat Lake than downstream, possibly because of the greater influence of municipal discharges, the runoff from more moist and intensely farmed land, and the greater influence of tributaries on river water quality in the western portion of the basin. Indeed, most of these tributaries have higher colour levels than the Battle River and since they contribute relatively more water to the river they may influence colour levels more than tributaries to the lower portion of the basin. Extremes in the tributary colour levels were Pigeon Lake Creek with 14 RCU and Grattan Creek with 369 RCU.

Water quality concerns regarding colour are primarily aesthetic. A guideline for the colour of recreational water largely depends on the preferences of the user and there are no specific CWQG for true colour. AASWQIG specify that colour is not to be increased by more than 30 colour units above natural

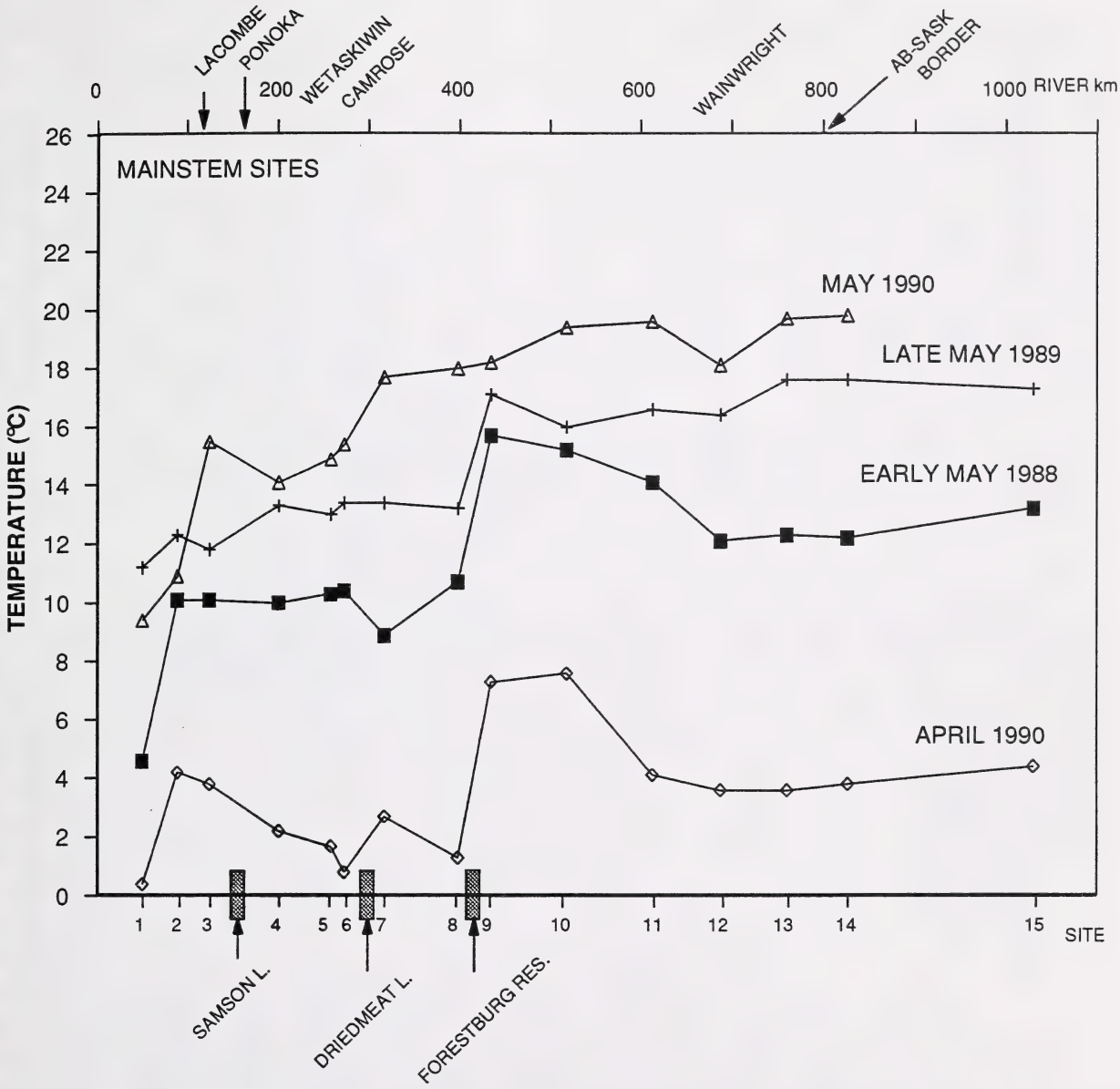
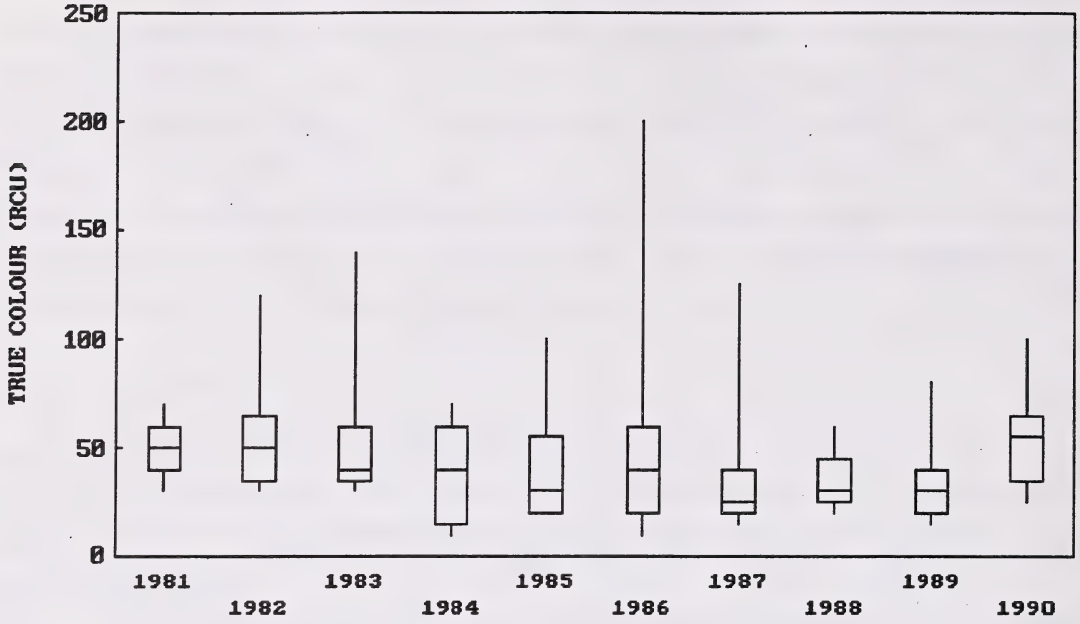


FIGURE 16. TEMPERATURE - longitudinal changes recorded during spring surveys in the Battle River.



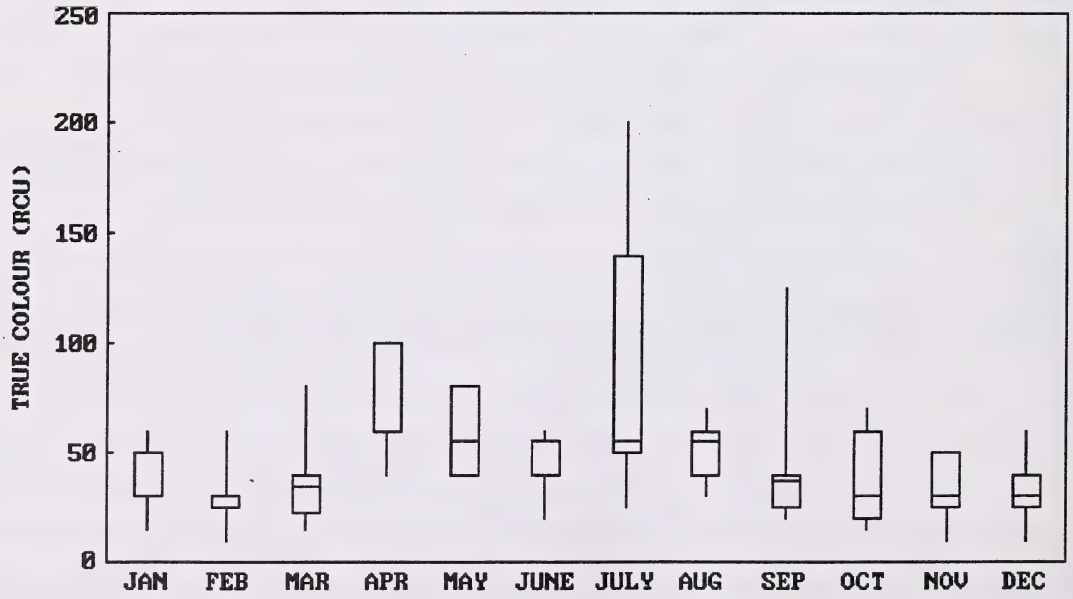


FIGURE 17. TRUE COLOUR - SEASONAL AND YEAR - TO - YEAR CHANGES AT UNWIN (1981 - 1990).

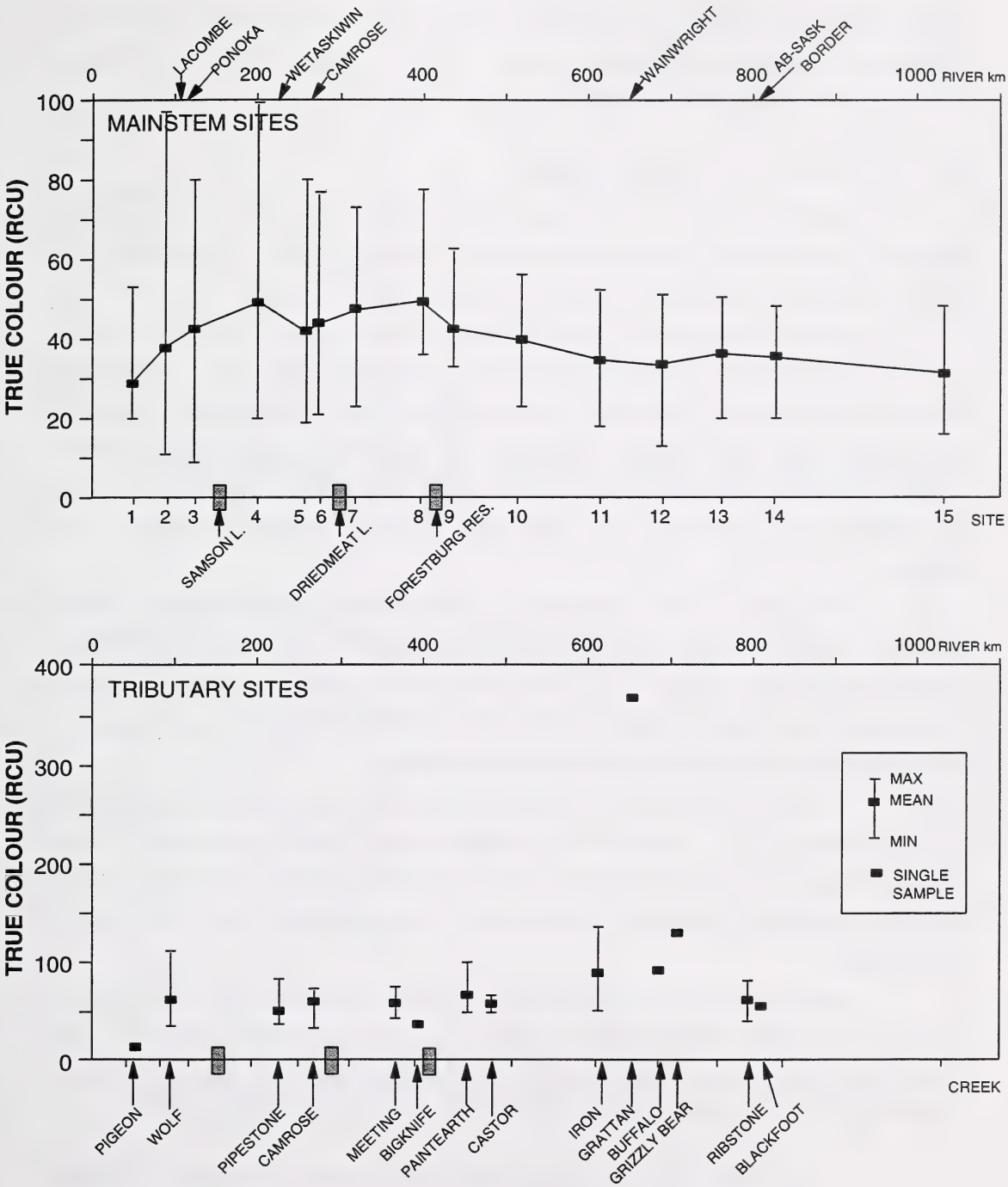


FIGURE 18. TRUE COLOUR in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

values. Average true colour values in the Battle River remained well within this range although site to site differences in individual synoptic surveys exceeded it on several occasions. Diffuse rather than point-sources are probably the largest contributor of colour to the Battle River.

4.3.1.3 Turbidity and Non-Filterable Residue

Turbidity is a measure of the scatter and absorption of light in water. It is caused by the presence of suspended matter, soluble coloured organic compounds and seston (CCREM 1987). Non-filterable residue (NFR) is a measure of the amount of suspended particulate matter.

NFR and turbidity were positively correlated with river discharge (Table 9). Consequently, seasonal changes in these two variables at Unwin reflect seasonal hydrographic changes. Highest median values of NFR and turbidity coincide with spring runoff and are indicative of the high loads of particulate matter transported at that time (Figure 19). Median values ranged from a high of 200 mg/L NFR, and 80 JTU for turbidity in April to values below 10 mg/L and 10 JTU in the winter. Sharp increases in NFR and turbidity in summer usually coincide with sudden increases in river discharge following heavy rainstorms.

Trend analysis on the long-term data set indicated that a significant increase in NFR and turbidity has occurred over the period of record (Table 10, Figure 19). The reason for this increase is unclear and is apparently unrelated to river discharge, which has not changed significantly. Compared to in-stream levels, these changes (0.4 mg/L.yr and 0.6 JTU/yr for NFR and turbidity, respectively) are very small and have had an insignificant effect on in-stream water quality.

The relationship between NFR, turbidity and discharge was also apparent in survey data from 1989-1990 (Figure 20, 21). Average NFR and turbidity increased steadily in a downstream direction, reflecting the gradual increase in river discharge. Maximum NFR and turbidity was recorded during the April 1990 survey during spring runoff; minima generally occurred during the winter (NFR) or in May 1990 (turbidity).

Smaller tributaries in the lower portion of the basin were sampled in May 1990 only at very low flows. These single records suggest that turbidity is low in these tributaries, compared to others. However, single measurements should not be compared with those from other tributaries which were sampled under a wider range of flow conditions.

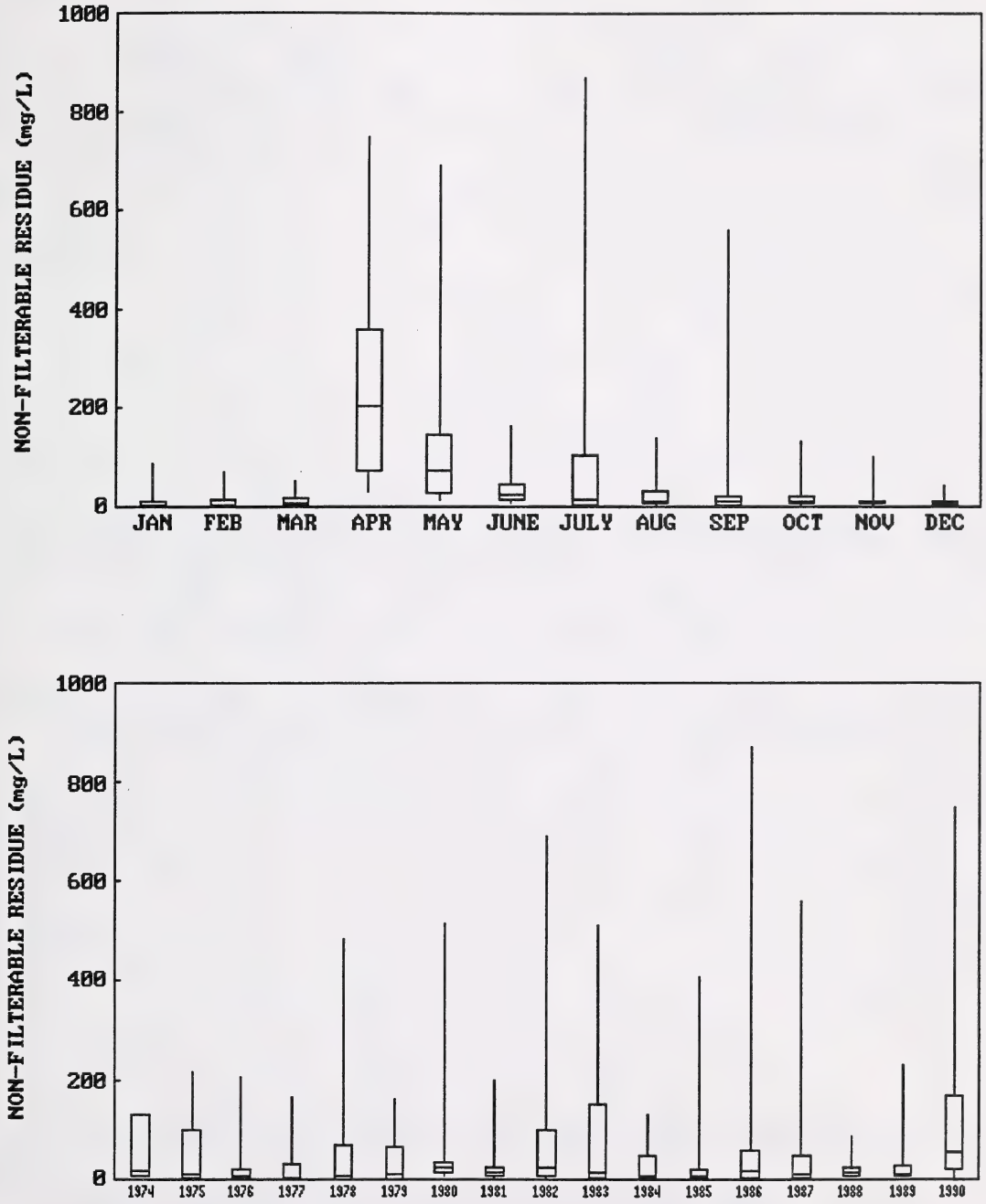


FIGURE 19. NON-FILTERABLE RESIDUE-SEASONAL AND YEAR-TO-YEAR CHANGES AT UNWIN (1974-1990)

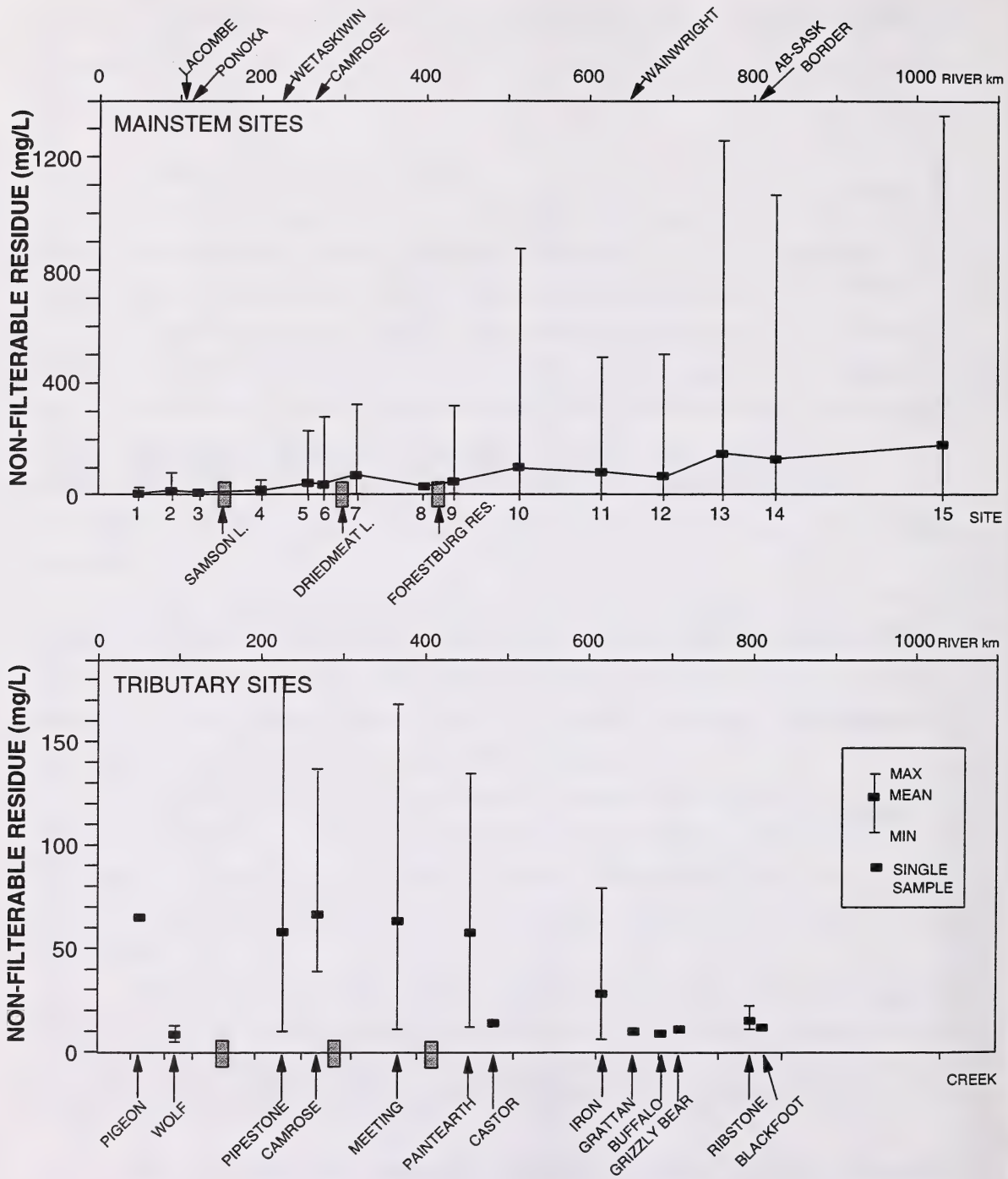


FIGURE 20. NON-FILTERABLE RESIDUE in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

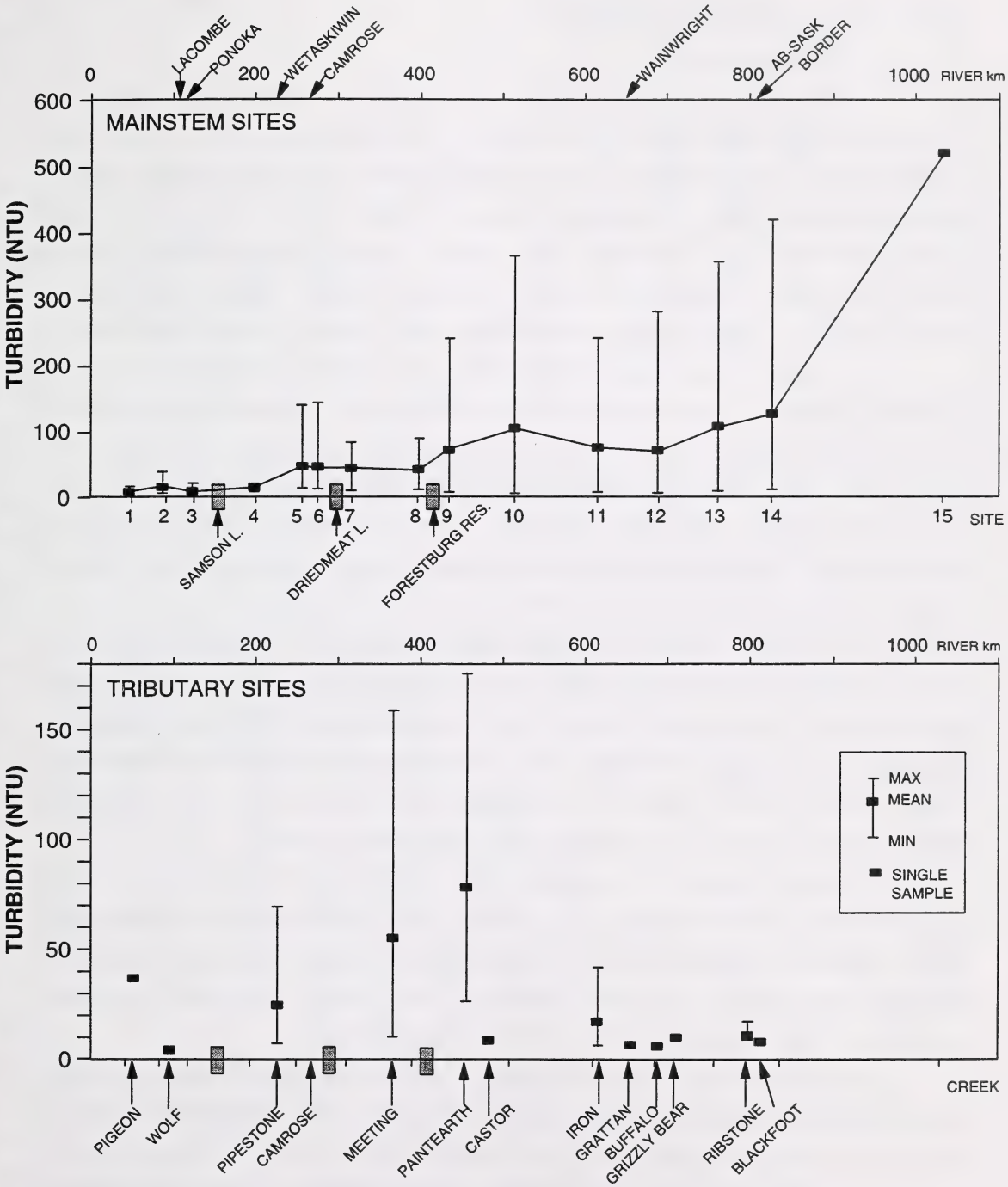


FIGURE 21. TURBIDITY in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

4.3.2 Major Ions and Related Variables

4.3.2.1 pH and Alkalinity

Alkalinity is a measure of water's ability to neutralize acids. Alkalinity is primarily controlled by bicarbonate species and is often expressed as $CaCO_3$. This expression assumes that alkalinity results only from $CaCO_3$ and HCO_3^- and it may imply the presence of more calcium than is actually present in saline waters (Wetzel 1983). pH is usually defined as the negative logarithm of the reciprocal of the concentration of free hydrogen ions (Wetzel 1983). In aquatic systems, pH and alkalinity are usually the product of the geology and geochemistry of rocks and soils in the basin. Biological activity, nutrient cycling, and industrial effluents can influence the variability of pH in aquatic systems (CCREM 1987).

No significant trends were recorded over the period of record in pH and alkalinity at Unwin (Table 10). Alkalinity was inversely correlated to flow (Table 9) as were bicarbonate and other major ions. Median alkalinity was more than 250 mg/L lower in April (high flow) than in January (low flow) (Figure 22). pH was independent of flow (Table 9). Weak seasonal changes were reflected in slightly lower medians during the winter (pH approximately 7.5) compared with the open water season (pH approximately 8.4). Increased photosynthetic activity during the summer, combined with lower alkalinity at that time, could account for part of these differences.

The 1989-90 average pH increased rapidly between site 1 (Highway 611) and site 4 (downstream Samson Lake) than anywhere else in the river (Figure 23). In contrast, average pH changed little downstream of Driedmeat Lake (range 8.2-8.4). The lowest single pH (6.9) was recorded at site 1, the highest (9.6) downstream of Driedmeat Lake. That site also had the largest seasonal range in pH values of all sites (7.1-9.6) and reflects the influence on the Battle River of Driedmeat Lake, a hypereutrophic lake with wide seasonal changes in pH (Mitchell and Prepas 1990).

Alkalinity in the Battle River increased steadily from 192 mg/L at site 1 to 338 mg/L at site 15 (Figure 24). The widest seasonal range (111 to 395 mg/L) was recorded downstream of Camrose Creek (site 6). Tributaries in the lower portion of the basin generally had a higher alkalinity than tributaries from the upper portion or than nearby sites on the Battle River. Extreme alkalinity values recorded in tributaries ranged from 161 mg/L in Pigeon Lake Creek to 933 mg/L in Grattan Creek.

There are no surface water quality guidelines for alkalinity, which varies naturally and widely in surface waters. Nevertheless, alkalinity in surface waters usually does not exceed 500 mg/L $CaCO_3$ (CCREM 1987); some values recorded in the Battle River, and especially in its tributaries, are very high.

For the protection of aquatic life CCREM (1987) and PPWBO recommend a pH range of 6.5 to 9; AASWQIG are more restrictive and recommend an upper limit of 8.5. Average pH values met

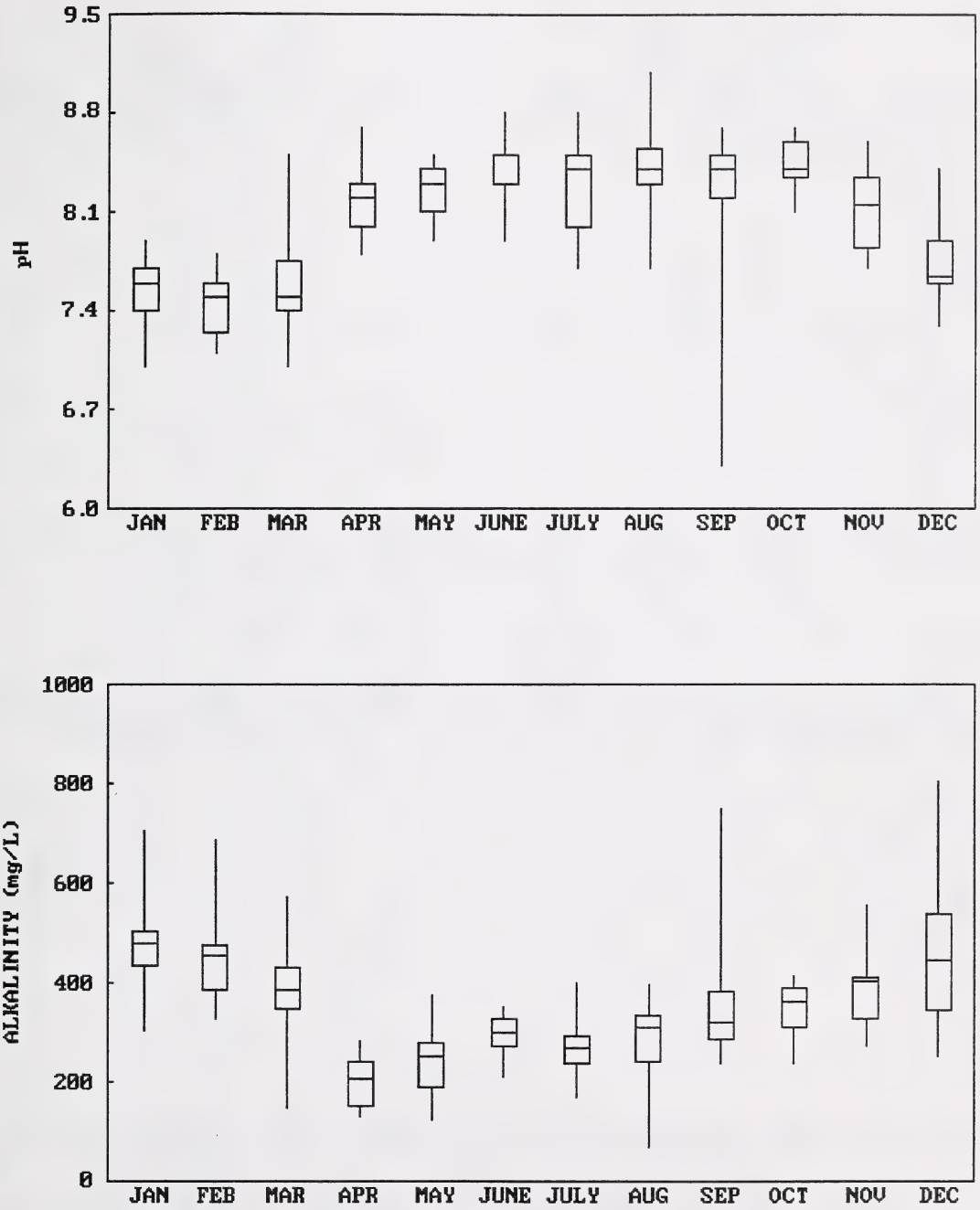


FIGURE 22. pH AND ALKALINITY-SEASONAL CHANGES AT UNWIN (1974-1990).

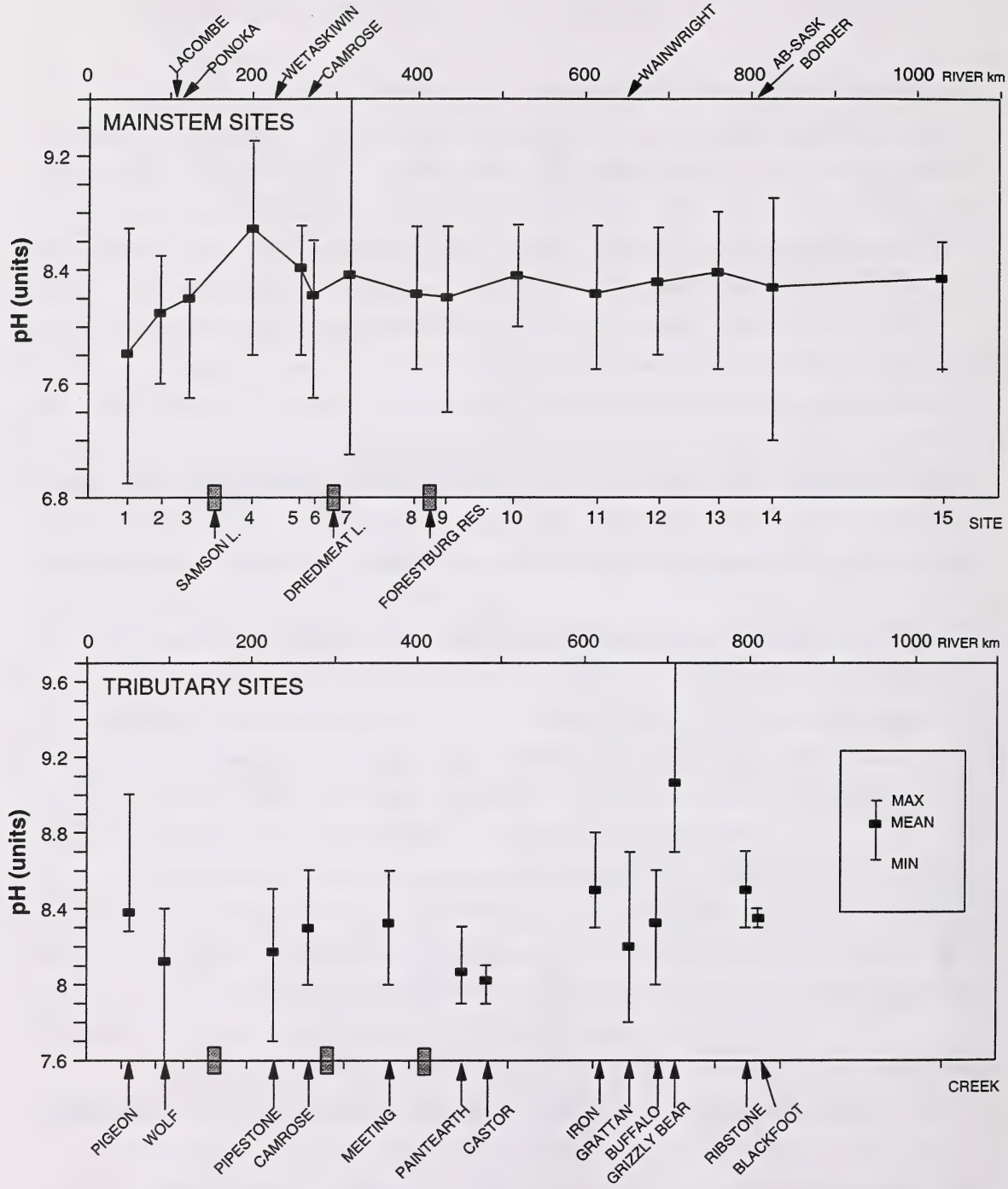


FIGURE 23. pH in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

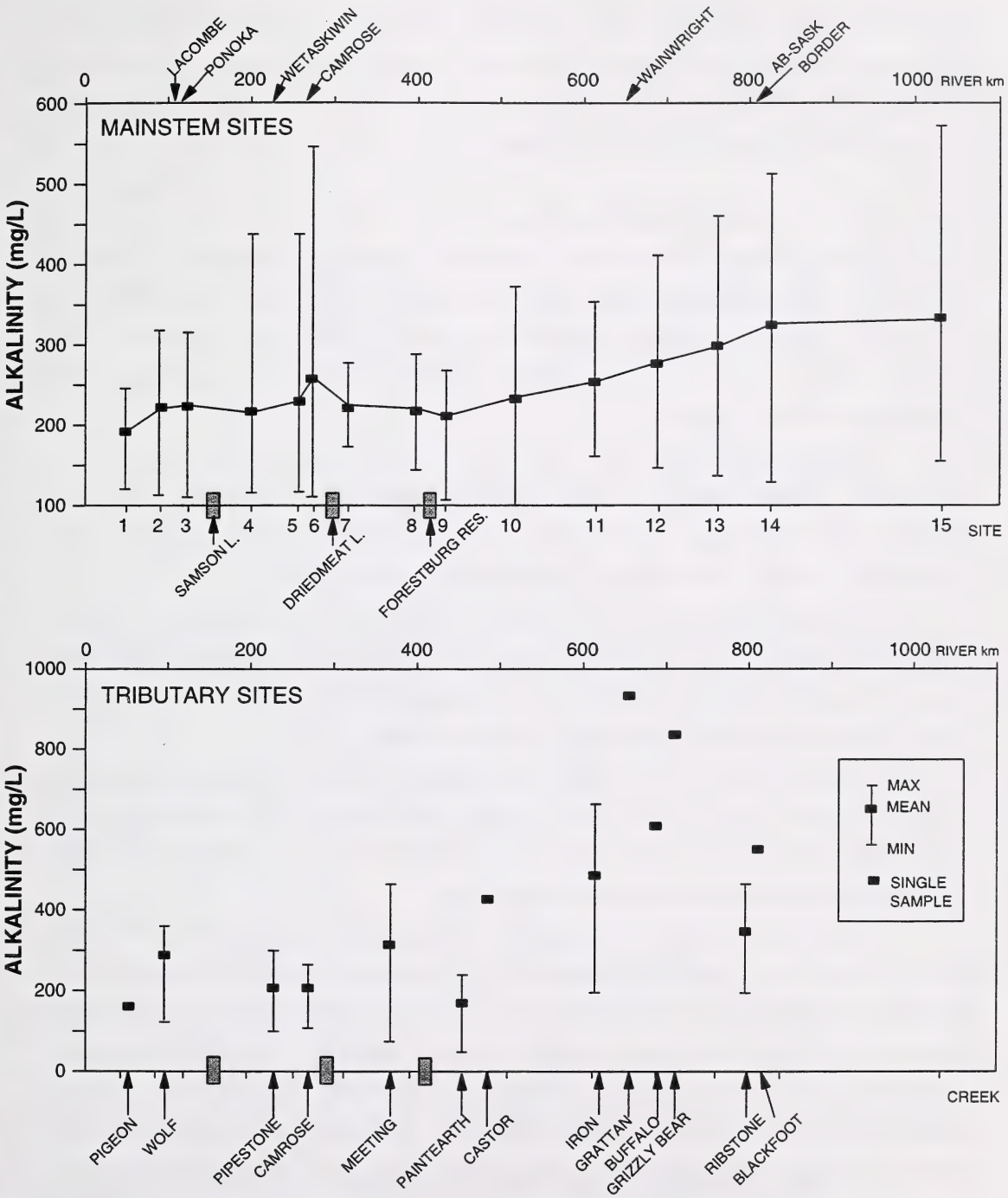


FIGURE 24. ALKALINITY in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

CWQG and PPWBO at all mainstem sites and all tributary sites except Grizzly Bear Creek. Extremes downstream of Samson Lake and Driedmeat Lake exceeded the upper limit of that range. AASWQIG were exceeded at nearly all mainstem and tributary sites by average and individual pH values. This is common in eutrophic plains systems, whether impacted by man or not.

4.3.2.2 Total Dissolved Solids and Conductivity

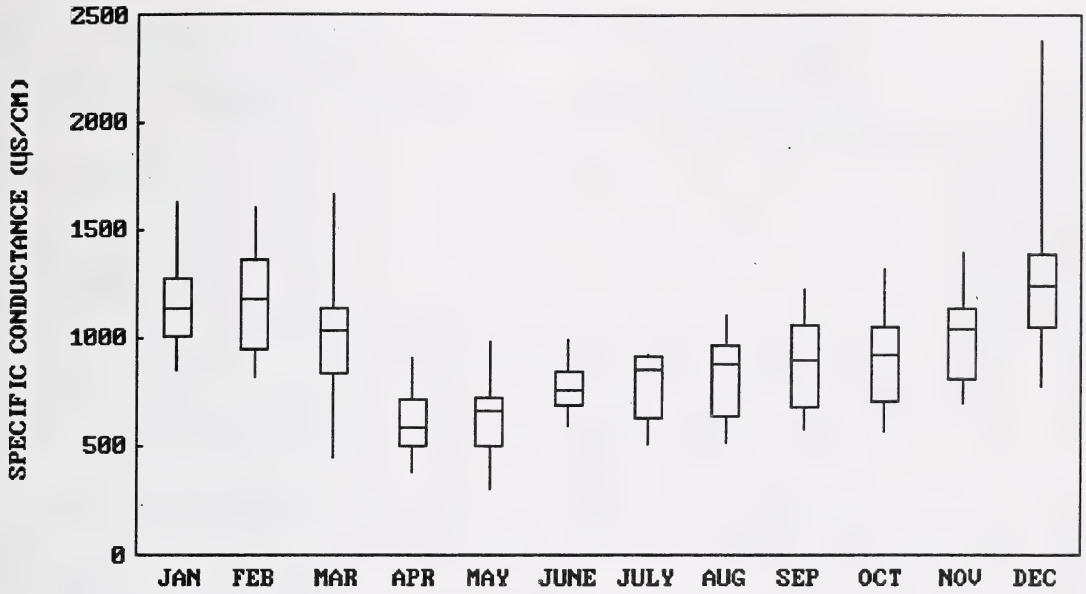
Specific conductance (conductivity) is a numerical expression of water's ability to conduct an electric current. The conductivity of water is particularly sensitive to variations in the make-up of its total dissolved solids (TDS), often mostly inorganic ions in water (CCREM 1987). Differences in the relationship between conductivity and TDS is influenced by differences in the dissociation constants of the various constituent dissolved solids.

Conductivity and TDS behaved very similarly in the Battle River at Unwin. As both variables were inversely correlated with river discharge (Table 9) minimum monthly medians (conductivity: 550 µS/cm; TDS: 400 mg/L) occurred in April and May at high flow; maximum monthly medians (conductivity: 1200 µS/cm; TDS: 750 mg/L) at low flows in winter (Figure 25).

Trend analysis identified a significant decline of 0.02 mg/L.yr in TDS (Table 10). However, as mentioned in section 4.1.2, persistent serial correlation in the data set could have influenced the outcome of the test. In any case, the decline in TDS was so small compared to in-stream concentrations that even if the trend is true it did not influence water quality at Unwin noticeably.

Survey data for 1989-1990 reflect a steady increase in average conductivity and TDS in a downstream direction, a feature which is common to many rivers (Whitton 1975). As expected from the seasonal patterns encountered at Unwin, conductivity and TDS maxima were recorded during winter surveys, minima were usually encountered in the spring survey.

As discussed in section 3.4, municipalities in the Battle River utilize groundwater as the main source of drinking water. The high salt content of this drinking water is reflected in the quality of the wastewater. Municipalities in the basin contribute to the salt load in the river (section 4.1.3) and in-stream conductivity is elevated during periods of effluent discharge (section 4.2). The influence of municipal effluent discharges is reflected in data from individual surveys (Figure 26). Information on the timing of discharges in the Battle River basin is shown in Figure 2. Increases in conductivity between site 2 (Highway 53) and site 3 (downstream Ponoka) coincide with or follow the discharges from Lacombe (early May 1989 survey) or Ponoka (May 1990 survey); increases between site 5 (Highway 21) and site 6 (downstream Camrose Creek) coincide with discharges from Camrose (early May 1989 and October 1990



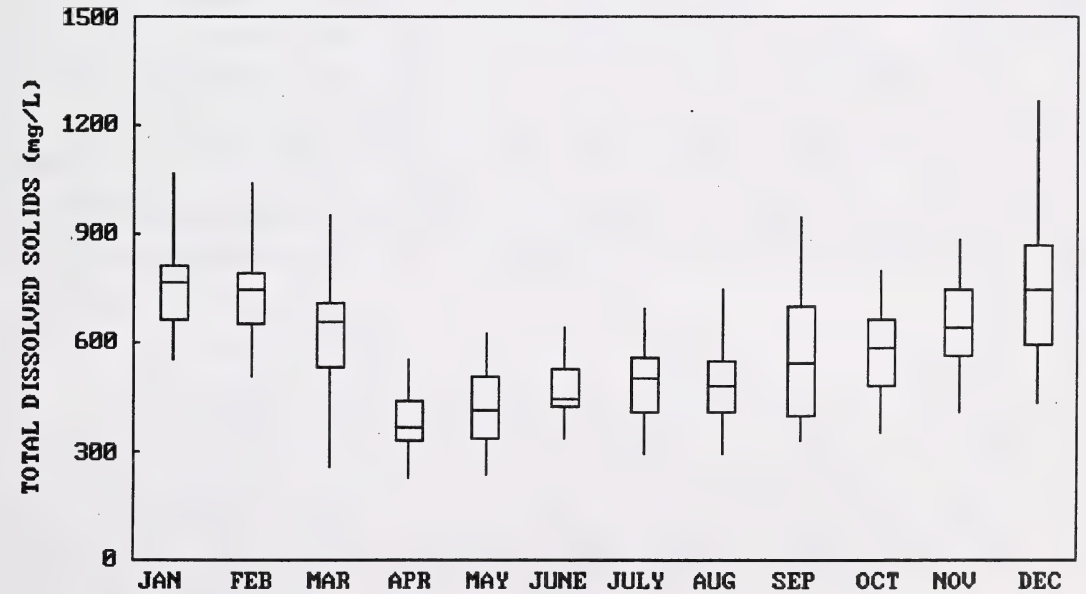


FIGURE 25. SPECIFIC CONDUCTANCE AND TOTAL DISSOLVED SOLIDS-SEASONAL CHANGES AT UNWIN (1974-1990).

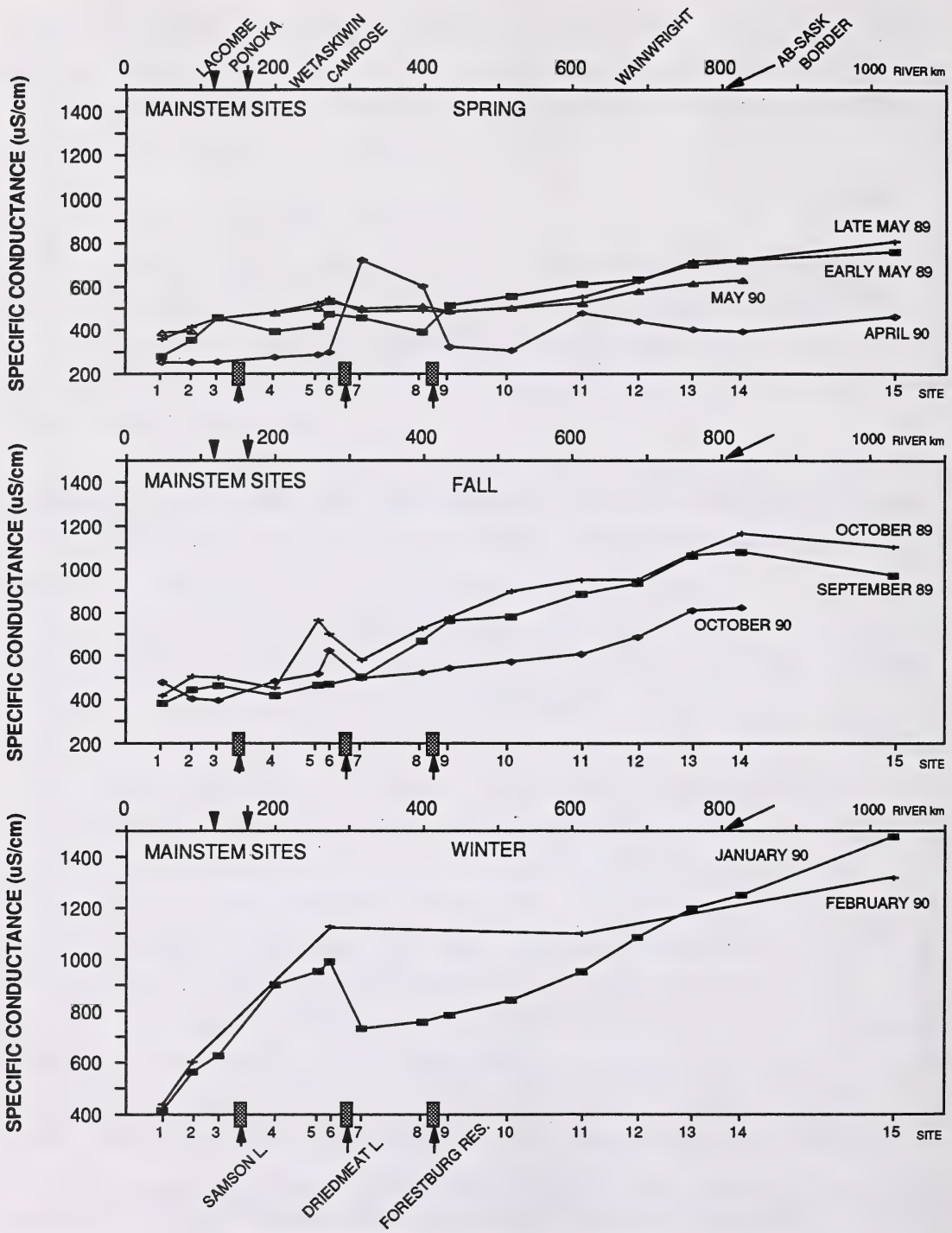


FIGURE 26. SPECIFIC CONDUCTANCE - longitudinal changes recorded during spring, fall, and winter surveys of the Battle River in 1989-1990.

survey), increases between site 4 (downstream Samson Lake) and site 5 (Highway 21) coincide with discharges from Wetaskiwin (October 1989 survey).

Driedmeat Lake also influences seasonal changes in conductivity and TDS in the Battle River. At the higher than average river flows during spring runoff 1990 (April 1990 survey), the lake outflow produced a three fold increase in conductivity and TDS of the river (Figure 26). However, during the winter, when little water flows out of the lake, in-stream conductivity and TDS are much lower downstream of the lake. Note the marked increase in conductivity downstream of Samson Lake and downstream of the Forestburg Reservoir during the winter survey, at a time of year when groundwater inputs are probably the main source of water in the river. Similar patterns for TDS and major ions suggest that this groundwater contains high levels of inorganic salts.

Conductivity and TDS of tributaries to the Battle River tend to increase in an eastward direction (Figures 27, 28). This trend reflects gradual changes in the type of soils or rocks occurring in the drainage basin of these tributaries.

On average, water in the Battle River and its tributaries has TDS concentrations less than 1000 mg/L and therefore qualifies as fresh water (CCREM 1987). However, tributaries in the eastern portion of the basin exceed this threshold value at low flow and supply slightly saline or brackish water to the Battle River. Ribstone Creek is unlike other tributaries in the eastern portion of the basin; its conductivity and TDS ranges are comparable to those of tributaries in the west.

On average, and according to CWQG and PPWBO, Battle River water is suitable for the irrigation of the most sensitive crops (TDS <500 mg/L). However, individual TDS measurements often exceed this threshold value and the suitability for irrigation needs to be assessed on a site-by-site basis. Restrictions are likely to become more severe in the eastern portion of the basin and at low river flow.

4.3.2.3 Major Ions and Hardness

Water hardness is a measure of dissolved cations, predominantly divalent cations. Calcium and magnesium are considered the primary contributors to hardness in natural waters (CCREM 1987). Calcium, magnesium, sodium, potassium, bicarbonate/carbonate, sulphate and chloride are described as major ions (Wetzel 1983). Fluoride, a minor anion, is also discussed in this section. Weathering of rocks, leaching, seepage, and runoff from soils are the main natural source of hardness and inorganic ions to surface waters (CCREM 1987). Anthropogenic sources include various industrial activities, salting of roads, treatment of domestic drinking and waste water, and agriculture.

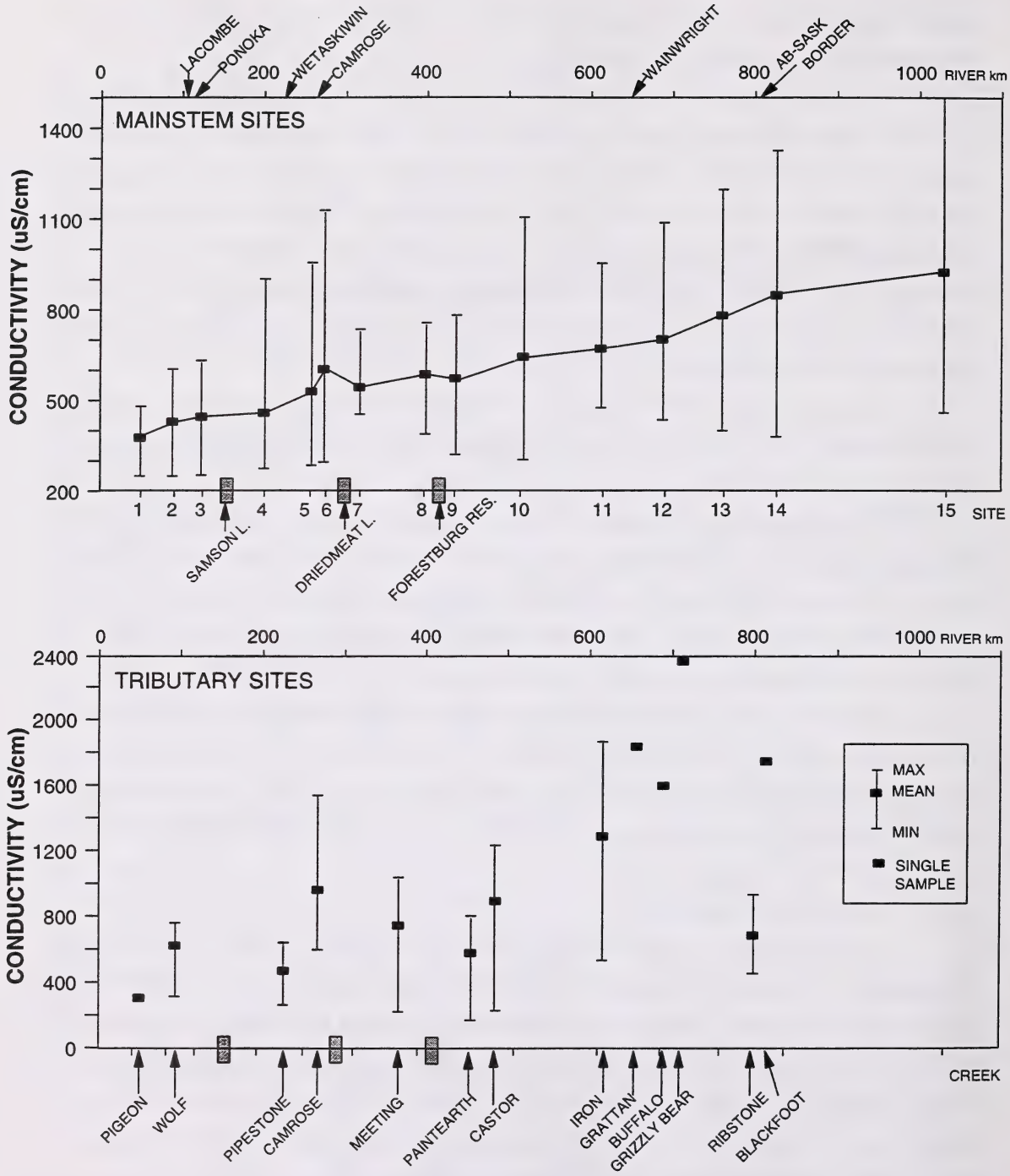


FIGURE 27. CONDUCTIVITY in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

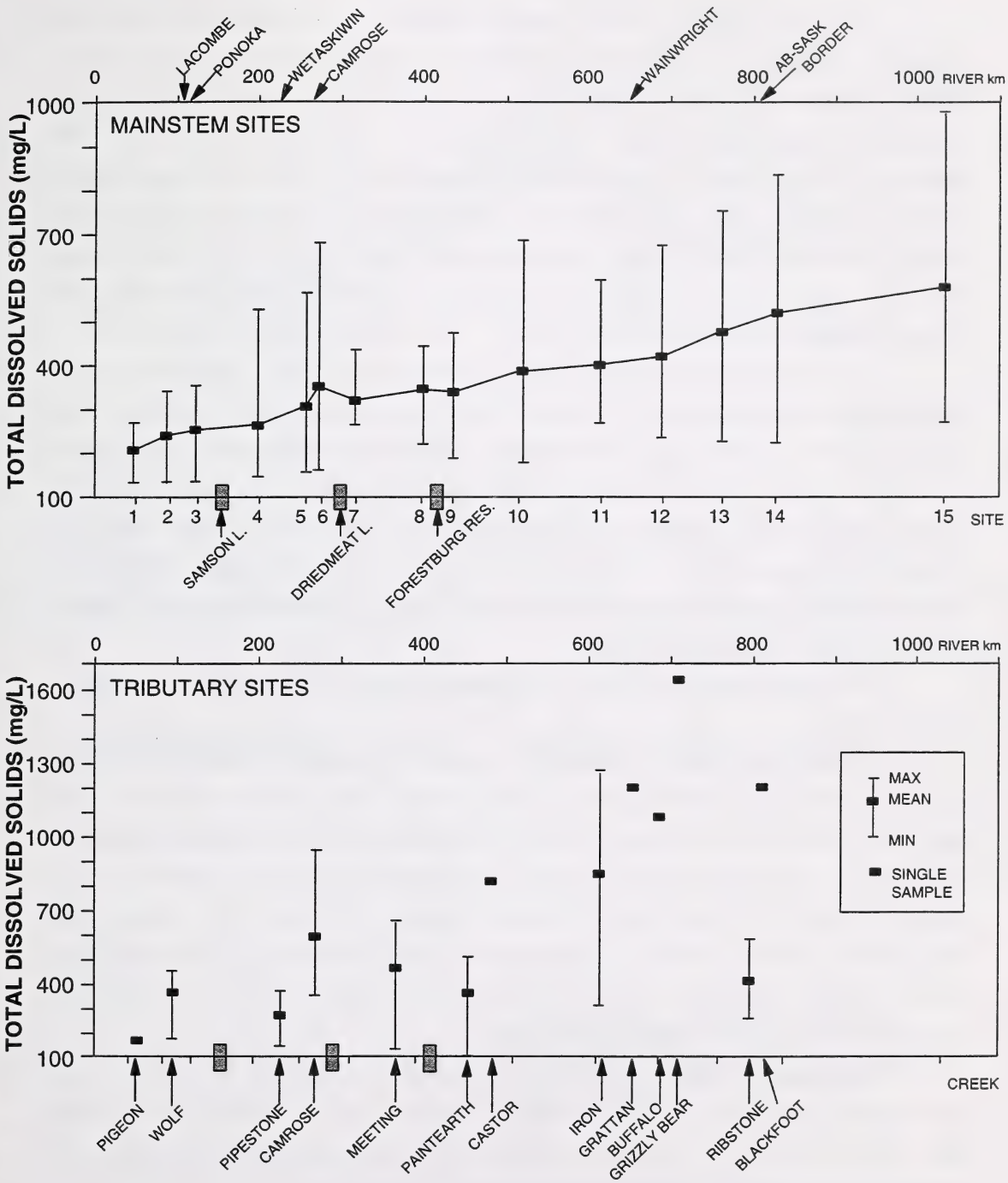


FIGURE 28. TOTAL DISSOLVED SOLIDS in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

Hardness, magnesium, sodium, sulphate, chloride, and bicarbonate showed an inverse relationship with flows, whereas calcium and potassium concentrations varied independently of flow (Table 9). Whitton (1975) points out that an inverse relationship between dissolved ions and flow rate is indicative of a constant input which is homogenously dissolved and mixed with river water. When concentrations remain constant an equilibrium between water and soils may exist or concentrations may approach a saturation value. The lowest median concentrations for flow dependent variables coincided with high river flows in April and May; highest concentrations coincided with low river flows in winter (Figure 29). Inputs of sodium, sulphate and chloride-rich groundwater would accentuate the inverse relationship of these ions and flow.

Significant declines in hardness, sodium, magnesium and sulphate were detected over the period of record at Unwin (Table 10). As indicated in section 4.1.2, serial correlation may have affected the outcome of the analysis for sodium and magnesium, but not the other two variables. The declines of 1.02, 1.05, 1.02, and 1.07 mg/L.yr recorded for hardness, sodium, magnesium and sulphate, respectively, are very small compared to in-stream concentrations and have had little effect on in-stream water quality (Figure 30). Although a decline in hardness could be linked to a decline in sodium, magnesium and sulphate levels, the reason for the concentration change in the these three variables is not clear. Changes in groundwater flow or quality may be involved.

The Unwin data set for fluoride was unsuitable for trend analysis because of repeated changes in methodology.

Table 16 shows the relative importance of major ions (expressed as meq/L) at sites sampled during 1989-1990 surveys. Although there was a definite increase in the importance of SO_4^{--} and Cl^- ions and a decline in HCO_3^- ions in a downstream direction, anion dominance was characterized by the sequence $HCO_3^->SO_4^->Cl^-$ throughout the Battle River basin. Longitudinal patterns in cation dominance were less consistent (Table 16). The upper portion of the basin (Highway 611 to Highway 2A, including Pigeon Lake and Wolf creeks) was typified by the dominance sequence $Ca^{++}>Na^+>Mg>K^+$. At all remaining sites in the basin, Na^+ was dominant over Ca^{++}. Potassium was dominant over Mg^{++} in the river stretch downstream of Samson Lake to downstream of Hardisty.

Although most creeks tended to have a similar ionic composition to that of nearby river sites, two creeks were quite different. Sulphate, sodium, and chloride were more important in Camrose Creek than at nearby mainstem sites. Sulphate and sodium were less important and bicarbonate and calcium more important in Ribstone Creek than in nearby mainstem sites or tributaries.

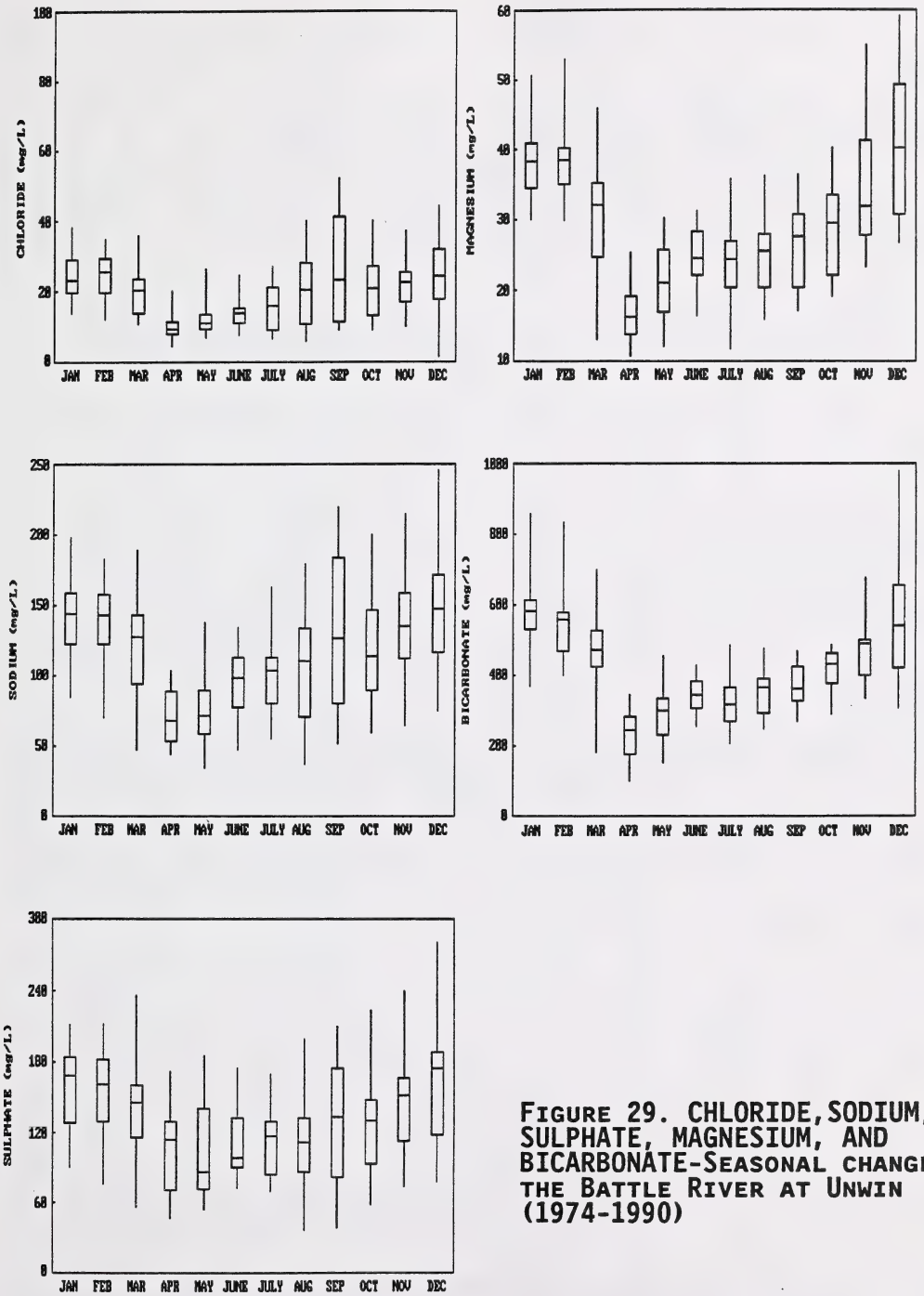


FIGURE 29. CHLORIDE, SODIUM, SULPHATE, MAGNESIUM, AND BICARBONATE-SEASONAL CHANGES IN THE BATTLE RIVER AT UNWIN (1974-1990)

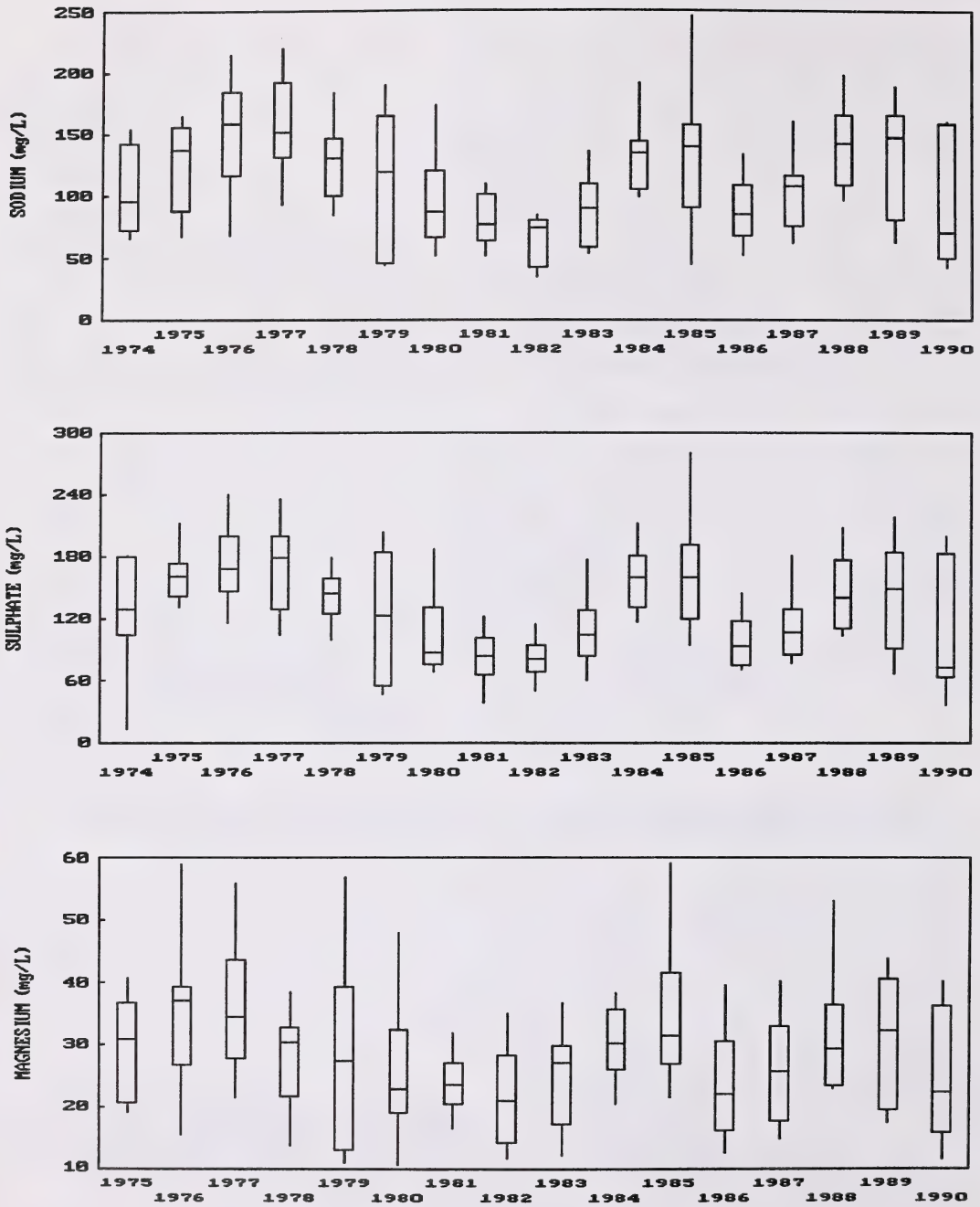


FIGURE 30. SODIUM, SULPHATE, AND MAGNESIUM-YEAR TO YEAR VARIABILITY IN THE BATTLE RIVER AT UNWIN (1974-1990)

Table 16. Anion and cation dominance (expressed as percent of total meq/L) of major ions in the Battle River basin (1989-1990).

	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
MAINSTEM SITES							
Highway 611	96.2	0.6	3.2	46.5	9.8	35.7	8.0
Highway 53	95.8	0.6	3.6	43.6	10.4	36.5	9.5
Highway 2A	93.9	1.1	5.0	42.4	9.9	38.1	9.6
Downstream Samson Lake	93.9	1.1	5.0	32.1	9.7	46.1	12.1
Highway 21	87.3	2.1	10.6	30.9	8.8	48.4	11.9
Downstream Camrose Crk	86.4	2.1	11.5	31.5	8.9	48.4	10.8
Highway 850	83.1	2.5	14.4	31.5	8.5	45.8	14.3
Upstream Forestburg	81.3	2.3	16.4	29.7	7.9	48.7	13.8
Highway 861	79.5	2.5	18.0	38.5	9.6	38.0	13.8
Downstream Hardisty	77.3	2.4	20.4	38.2	9.2	39.7	12.9
Highway 41	81.1	2.2	16.8	27.4	8.0	54.9	9.7
Highway 897	86.2	0.9	12.8	24.0	7.7	59.6	8.6
Unwin	78.6	2.4	19.0	24.2	7.9	59.8	8.1
Mouth	74.4	2.4	22.9	23.5	8.3	60.7	7.4
TRIBUTARY SITES							
Pigeon Lake Creek	96.7	0.6	3.7	47.3	10.7	28.0	14.0
Wolf Creek	89.9	2.4	7.6	44.3	8.4	20.0	27.3
Pipestone Creek	88.5	2.2	9.3	33.9	7.2	42.8	16.1
Camrose Creek	56.7	6.5	36.8	24.2	6.8	57.1	11.9
Meeting Creek	83.9	1.8	14.3	20.8	4.6	65.7	8.9
Paintearth Creek	67.4	1.5	31.2	20.8	3.7	66.5	8.9
Castor Creek	71.4	1.3	27.3	17.5	3.8	73.3	5.5
Iron Creek	75.5	1.1	24.4	15.0	9.8	66.9	8.3
Grattan Creek	71.4	1.3	27.3	8.5	6.2	81.8	3.5
Buffalo Creek	73.1	0.2	26.8	19.7	11.6	65.9	2.8
Grizzly Bear Creek	66.8	1.7	31.5	7.6	11.1	76.3	5.0
Ribstone Creek	91.1	0.8	8.1	31.6	12.2	49.7	6.4
Blackfoot Creek	63.0	0.5	36.4	16.5	10.4	66.9	6.3

Changes in ionic composition of Battle River water correspond broadly with changes in the ionic composition of surficial groundwater, which in turn is influenced by surficial and bedrock geology (section 3.1 and 3.2).

Longitudinal changes in ionic dominance were associated with longitudinal increases in total hardness and concentrations of all inorganic ions, particularly sodium, chloride and sulphate (Figure 31 to 39). Tributaries in the upper portion of the basin (i.e., Wolf, Pipestone and Camrose Creek) accounted for most of the increase in the sodium, chloride and sulphate loads recorded at nearby mainstem sites during the open water period (Table 11). As noted in sections 4.1 and 4.2.1, municipal discharges account for a considerable portion of the sodium and chloride load of the Battle River. Major ion composition in municipal wastewater reflects the general quality of the domestic raw water supply, but is also influenced by the treatment of the raw domestic water and by the addition of waste products. The importance of the contribution of municipal discharges to major ion concentrations is illustrated once again in Figure 40, which reflects longitudinal changes in chloride, sodium, and fluoride concentrations during fall surveys. Concentration peaks recorded at Highway 21 (site 5) in October 1989 and downstream of Camrose Creek (site 6) in October 1990 coincide with the wastewater discharge from Wetaskiwin and Camrose, respectively (Figure 2). As do many others in the basin, these two urban centers chlorinate, soften, and treat their domestic water with fluoride (pers. comm. C. Browning, Environmental Sciences Division). Relatively small increases were also recorded for sulphate and potassium, but concentrations of total hardness, calcium, magnesium, and bicarbonate were not affected.

Despite their high concentrations in major ions, tributaries from the eastern portion of the basin are too small to contribute much to the high loads of the river. Even municipal discharges from Wainwright, which contain saline water from Bushy Head Lake, represent less than 5% of the average daily sodium and chloride river load at the upstream site (Table 12, Appendix 7) and do not explain the increases in chloride, sodium, and sulphate observed downstream of Highway 41 (site 12). These increases are probably related to groundwater inputs.

Base flows in the winter are primarily the result of groundwater inputs. Longitudinal trends depicted for conductivity in the winter (Figure 26) are also typical of hardness, TDS, and major ions. They suggest that groundwater rich in dissolved substances enters the Battle River in the reach between Samson Lake and Driedmeat Lake and in the entire reach downstream of the Forestburg Reservoir.

There are no surface water quality guidelines for hardness. According to the CCREM (1987) classification, water in the Battle River and its tributaries qualifies as hard (120 to 180 mg/L) to very hard (more than 180 mg/L). The proportion of temporary or carbonate hardness (mainly due to calcium and

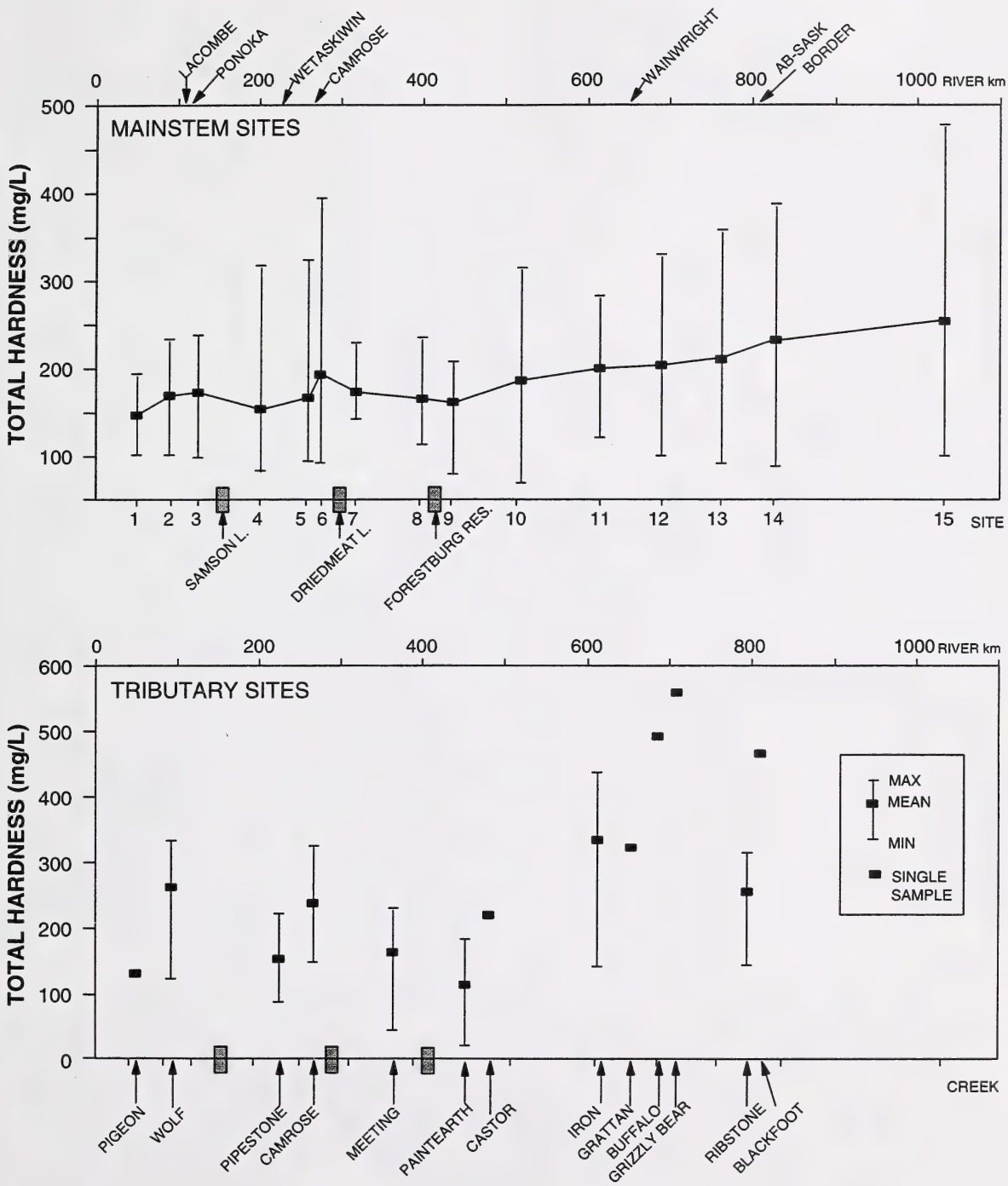


FIGURE 31. TOTAL HARDNESS in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

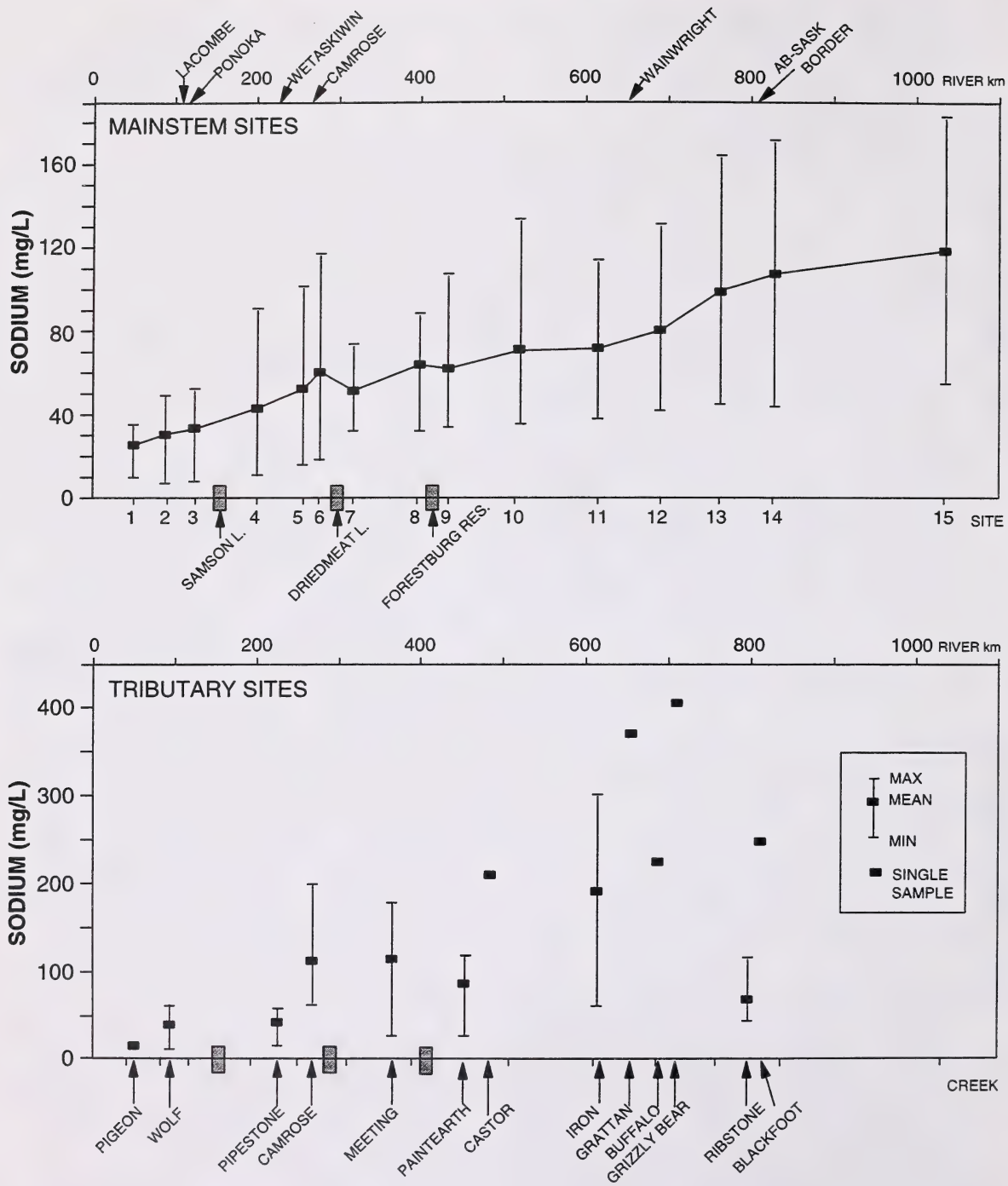


FIGURE 32. SODIUM in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

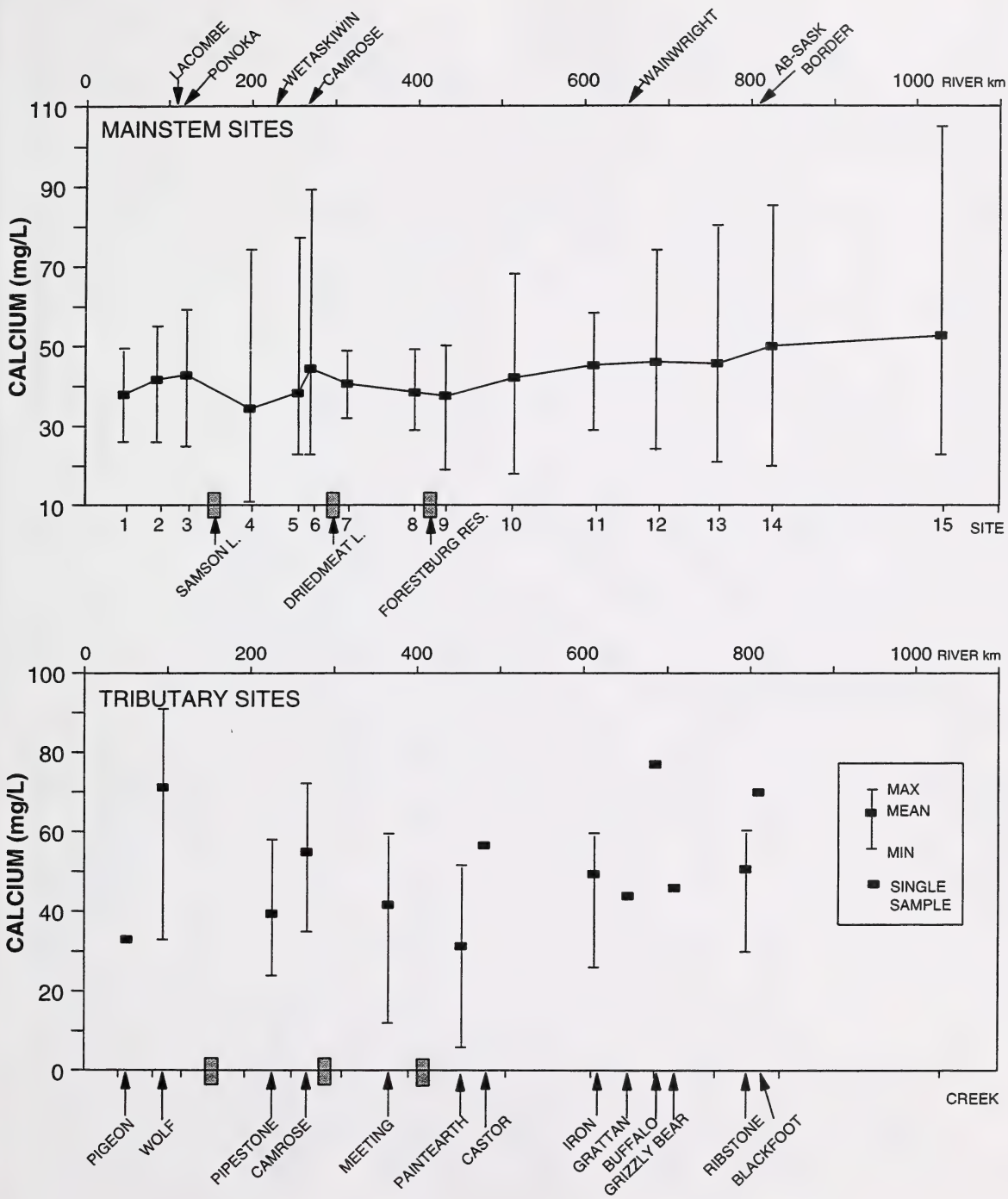


FIGURE 33. CALCIUM in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

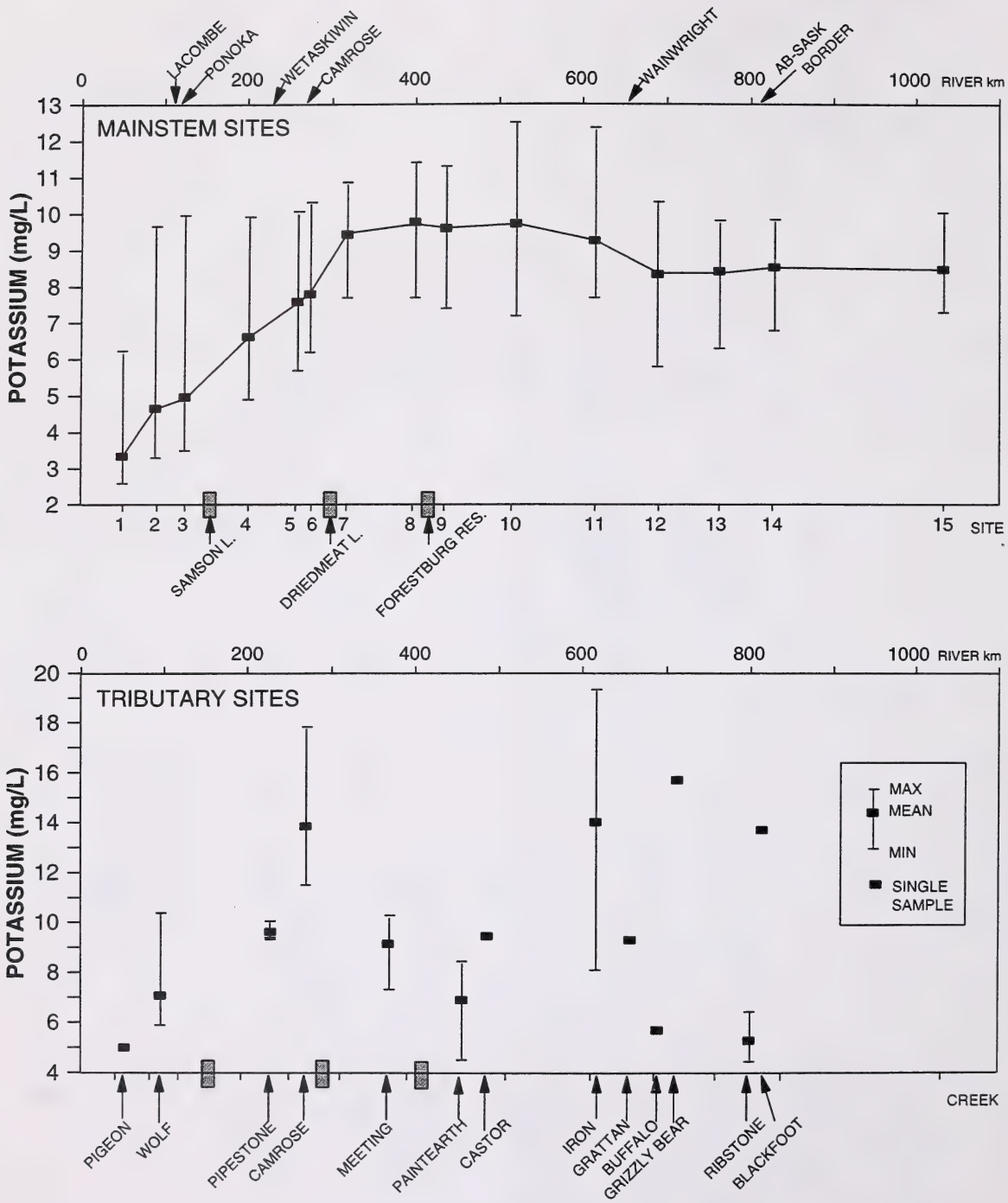


FIGURE 34. POTASSIUM in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

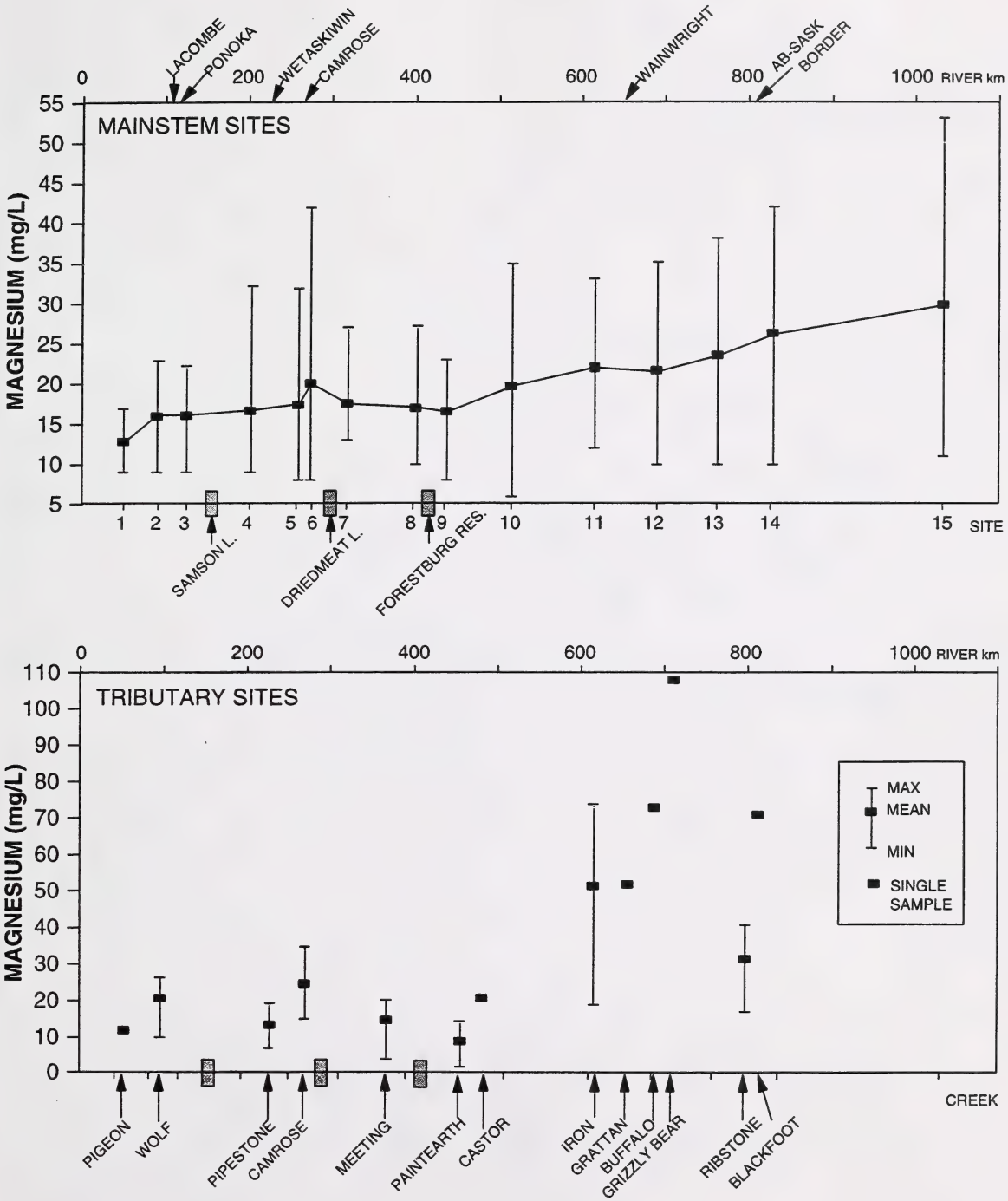


FIGURE 35. MAGNESIUM in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

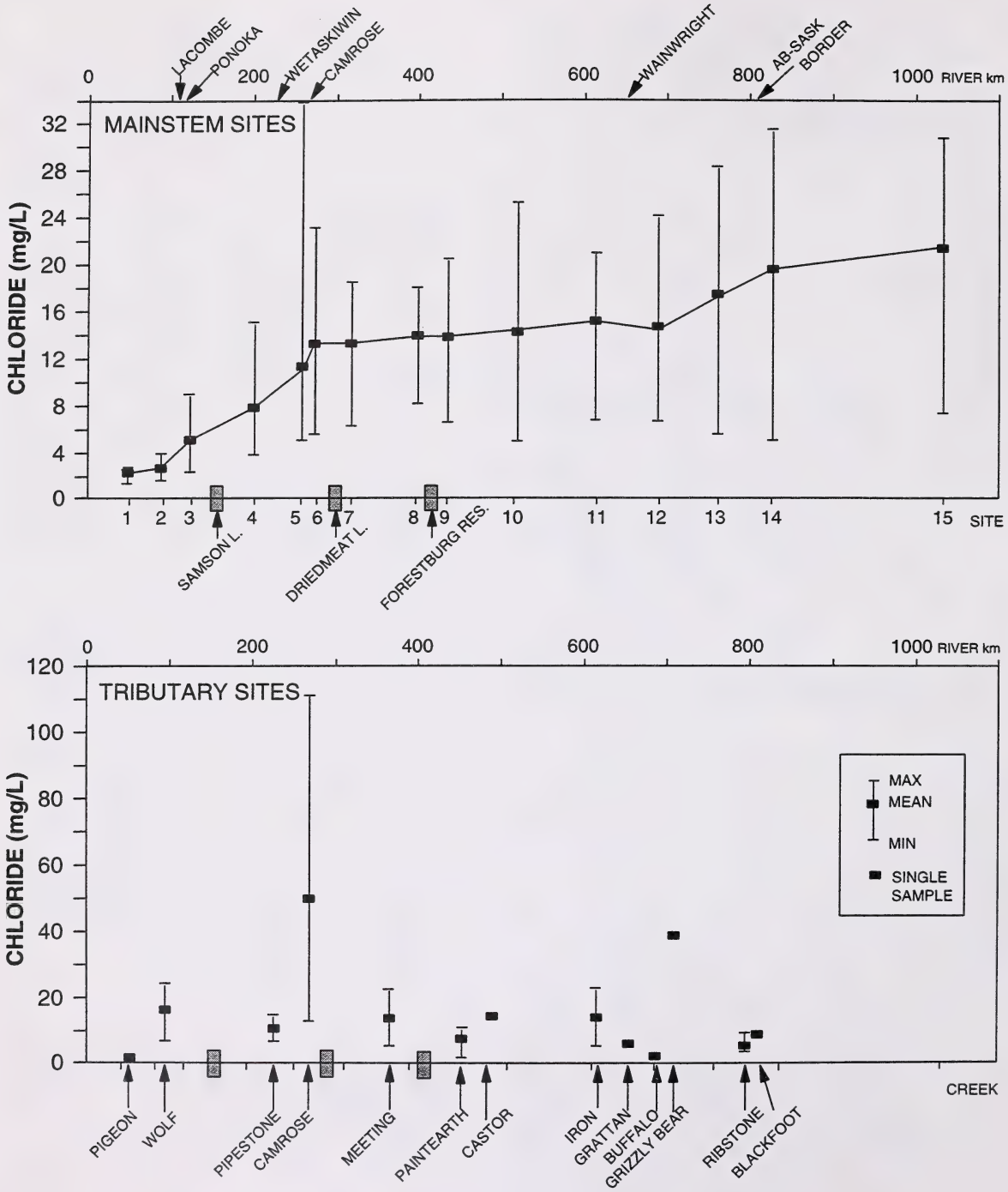


FIGURE 36. CHLORIDE in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

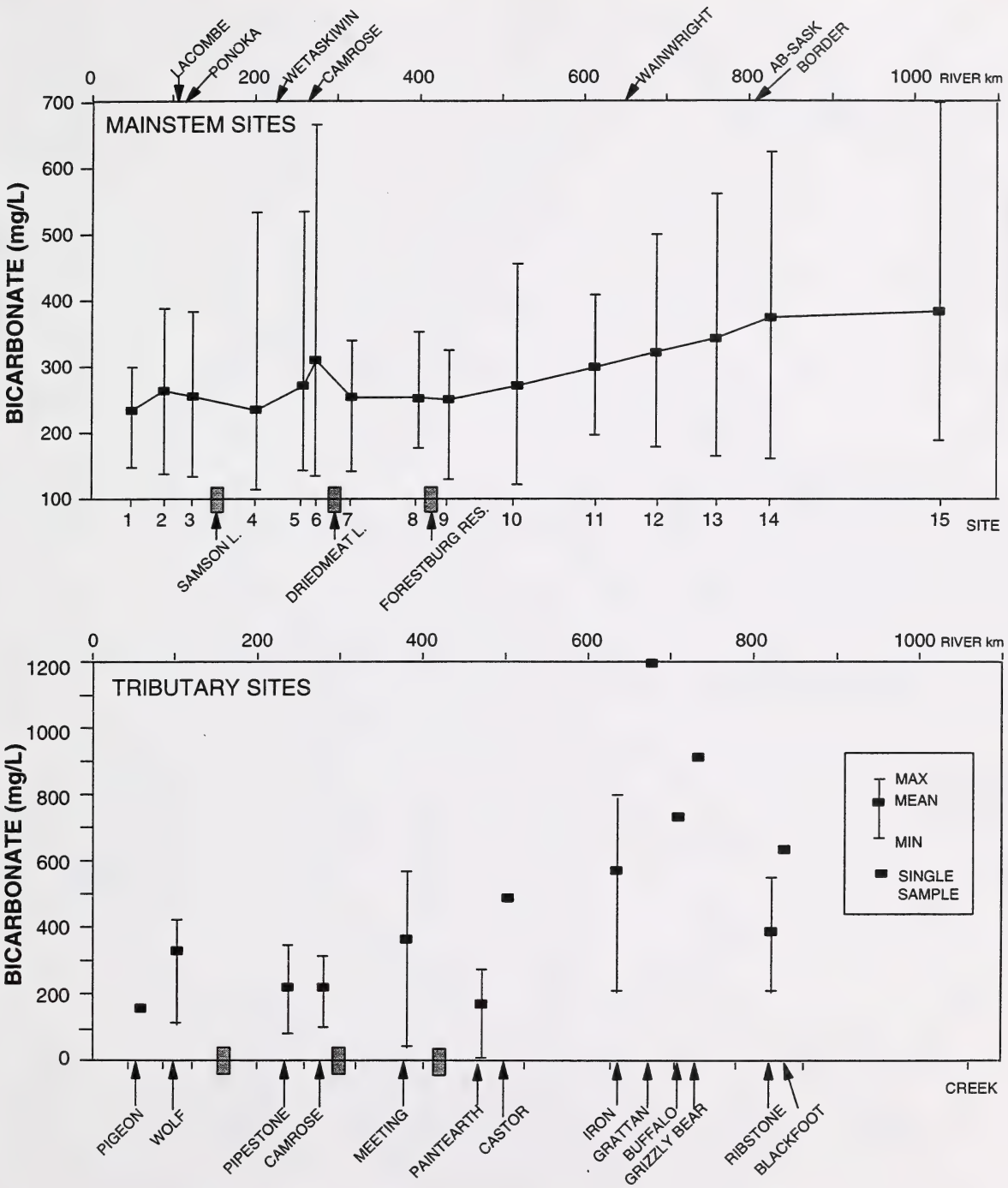


FIGURE 37. BICARBONATE in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

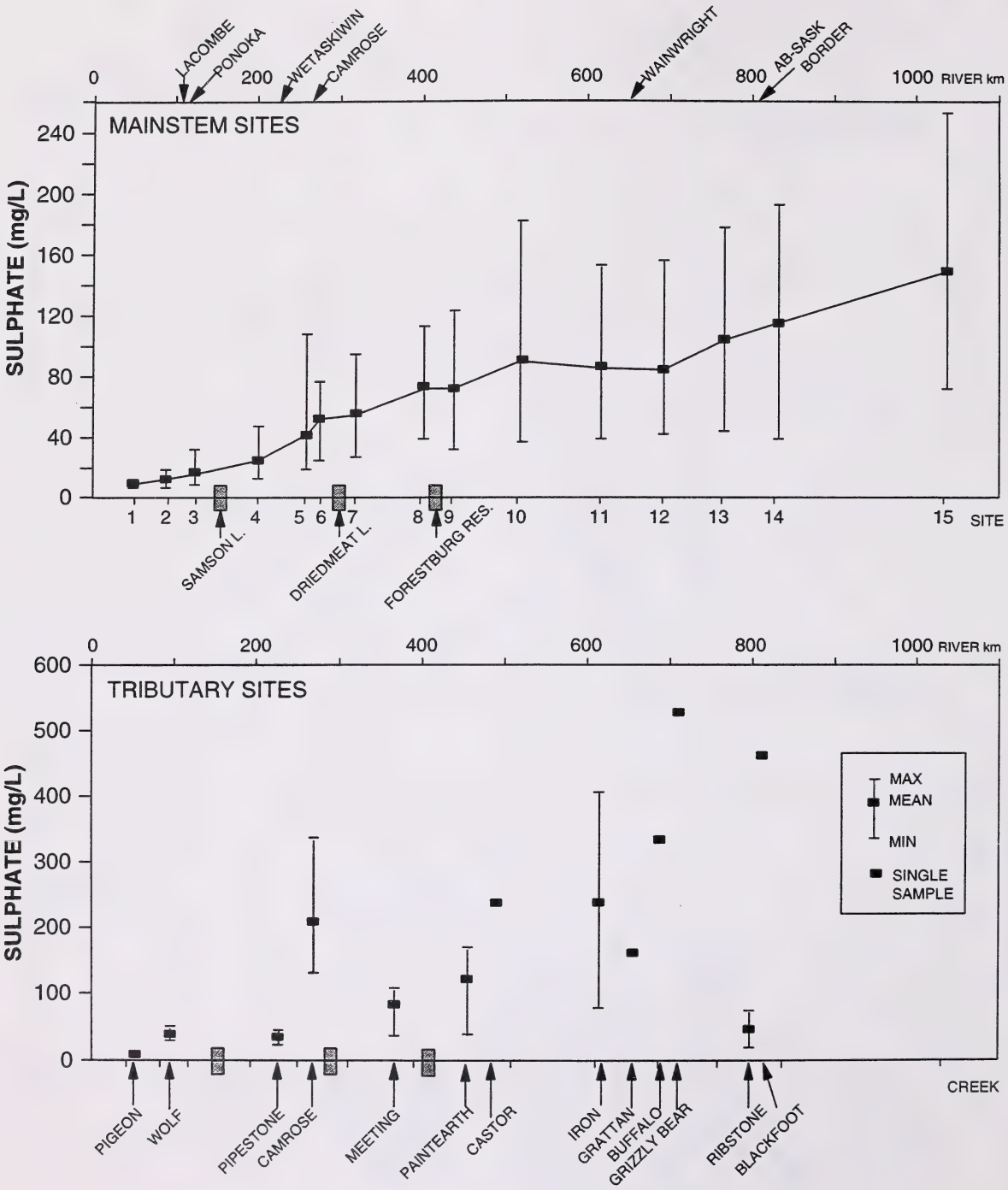


FIGURE 38. SULPHATE in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

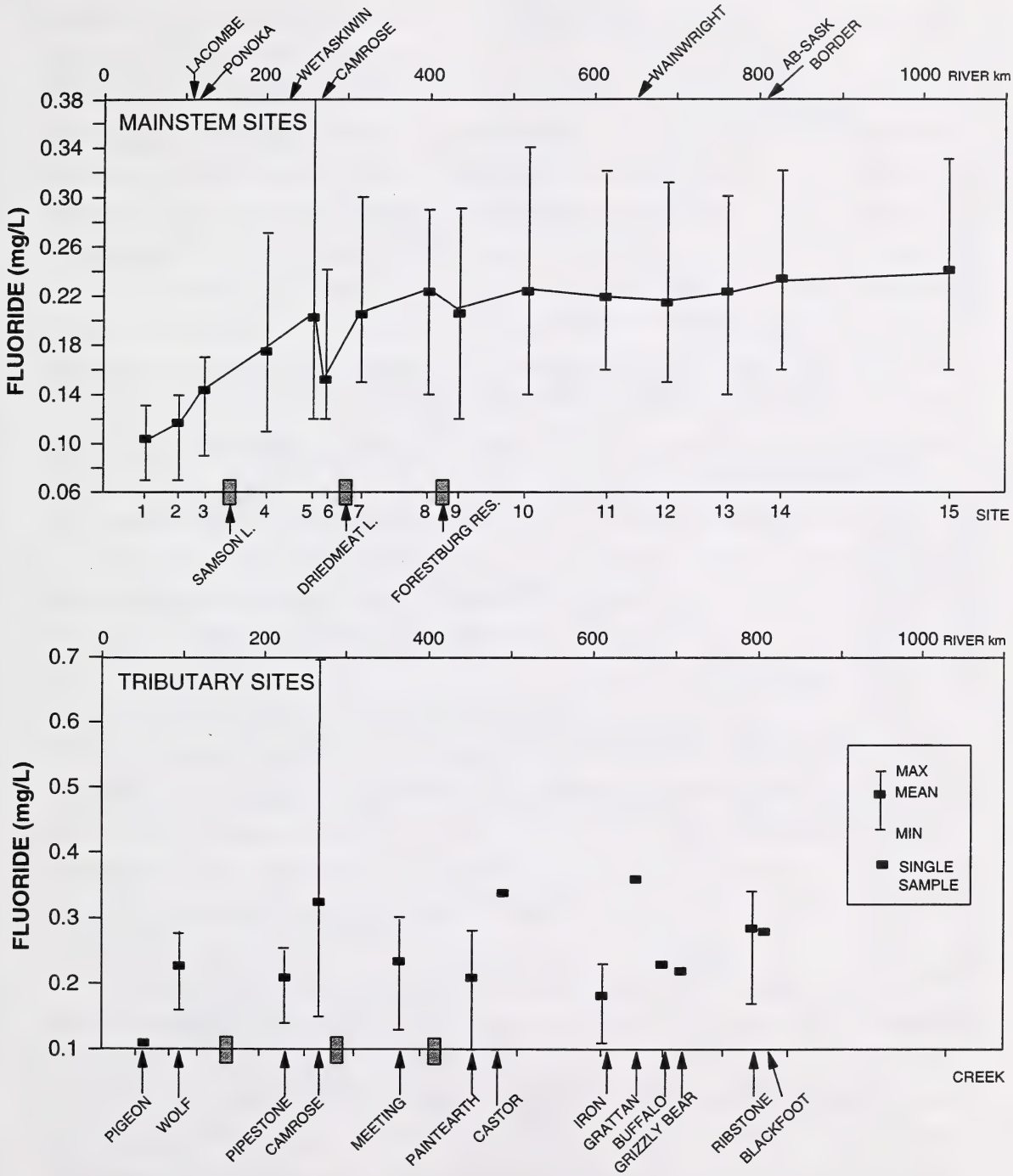


FIGURE 39. FLUORIDE in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

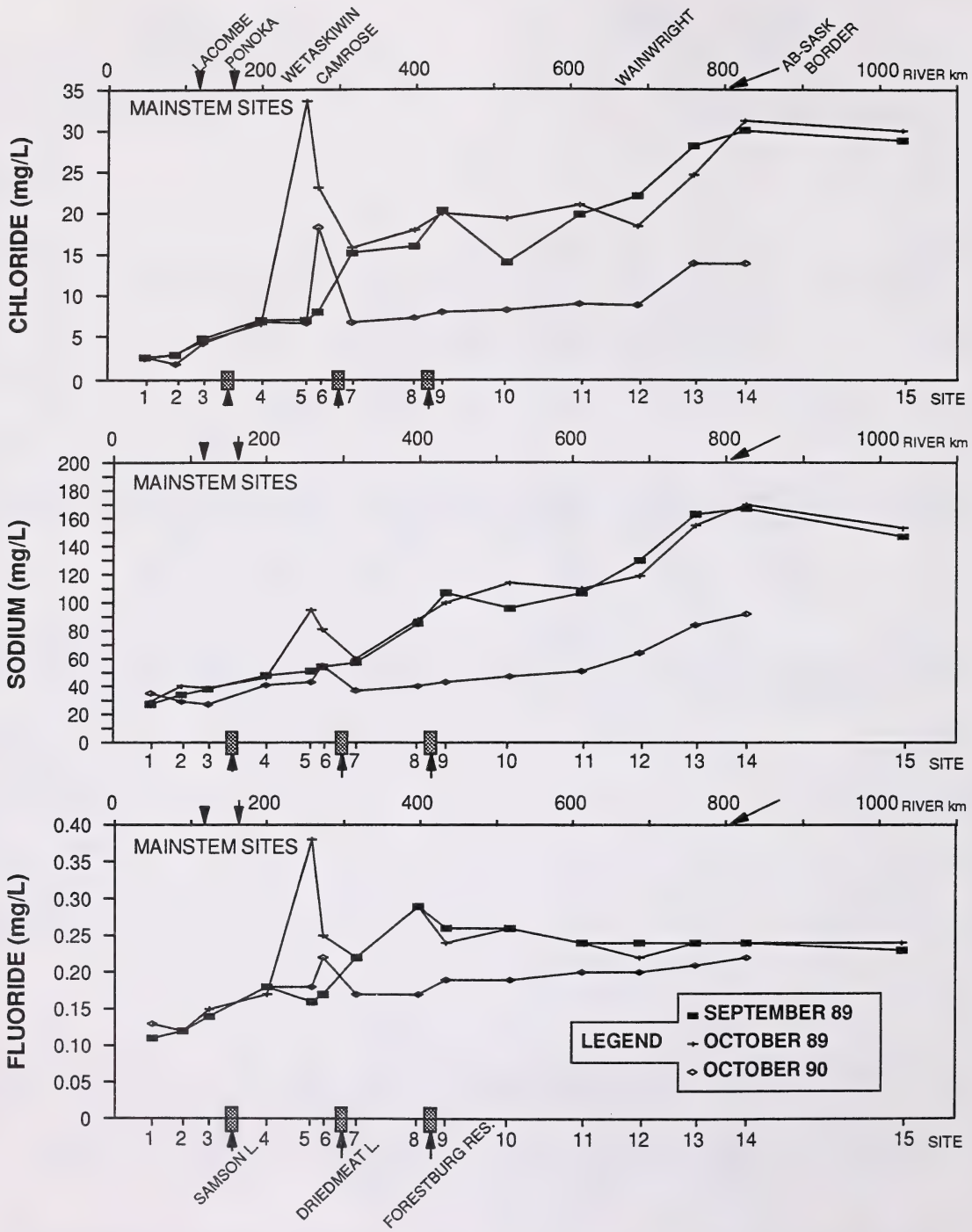


FIGURE 40. CHLORIDE, SODIUM, AND FLUORIDE - longitudinal changes recorded during fall surveys in the Battle River.

magnesium) declines as that of permanent or non-carbonate hardness (mainly due to sulphate, chloride and nitrate) increases in downstream direction.

The concentration and proportion of major ions in surface waters is particularly important if that water is to be used for irrigation. Additional critical factors such as evapo-transpiration, crop sensitivity, and structure and permeability of soils influence the quality requirements of irrigation water. Since these factors must be considered on a case-by-case basis, the suitability of Battle River water for irrigation water can only be discussed in general terms.

According to CWQG, chloride does not limit the use of Battle River water for irrigation. Sodium levels in the river, its tributaries in the Western portion of the basin, and Ribstone Creek are acceptable for the irrigation of all except the most sensitive crops. For sensitive crops, sodium levels exceed the recommended range (Na <115 mg/L). Water from tributaries in the lower portion of the basin is more severely limited by sodium content and is suitable only for the irrigation of tolerant and moderately tolerant crops (i.e., sodium concentration between 230 and 460 mg/L). PPWBO for irrigation water are more restrictive and recommend concentrations of sodium and chloride not greater than 100 mg/L and concentrations of sulphate not greater than 500 mg/L. These objectives are met for chloride and sulphate, but they are exceeded for average sodium concentrations in the lower portion of the basin and by maxima recorded in 1989-1990 at most mainstem and tributary sites.

4.3.3 Dissolved Oxygen and Biochemical Oxygen Demand

Dissolved oxygen (DO) is a fundamental constituent of natural waters. The solubility of oxygen in water is influenced by temperature, salinity, turbulence, atmospheric pressure, photosynthesis, aerobic respiration, and decay of organic material (Wetzel 1975, CCREM 1987). Oxygen from the atmosphere and from photosynthesis by chlorophyllous plants are the main sources of DO in water. Oxidation of reduced chemical compounds, aerobic respiration and decomposition of organic matter are the main causes of oxygen depletion.

Biochemical oxygen demand (BOD) is a measure of the amount of oxygen required for aerobic micro-organisms to oxidize organic matter to a stable organic form (CCREM 1987). BOD is determined following standardized laboratory procedures, usually over a 5-day period and at 20°C.

The Unwin data base was unsuitable for BOD trend analysis. Average BOD in the Battle River during the 1989-1990 surveys ranged from 2 to 4 mg/L at all sites except those between Samson Lake and the Forestburg Reservoir (site 4 to 8) where average values as high as 6 mg/L were recorded (Figure 41). These sites are influenced by the outflow from Samson and Driedmeat lakes which are

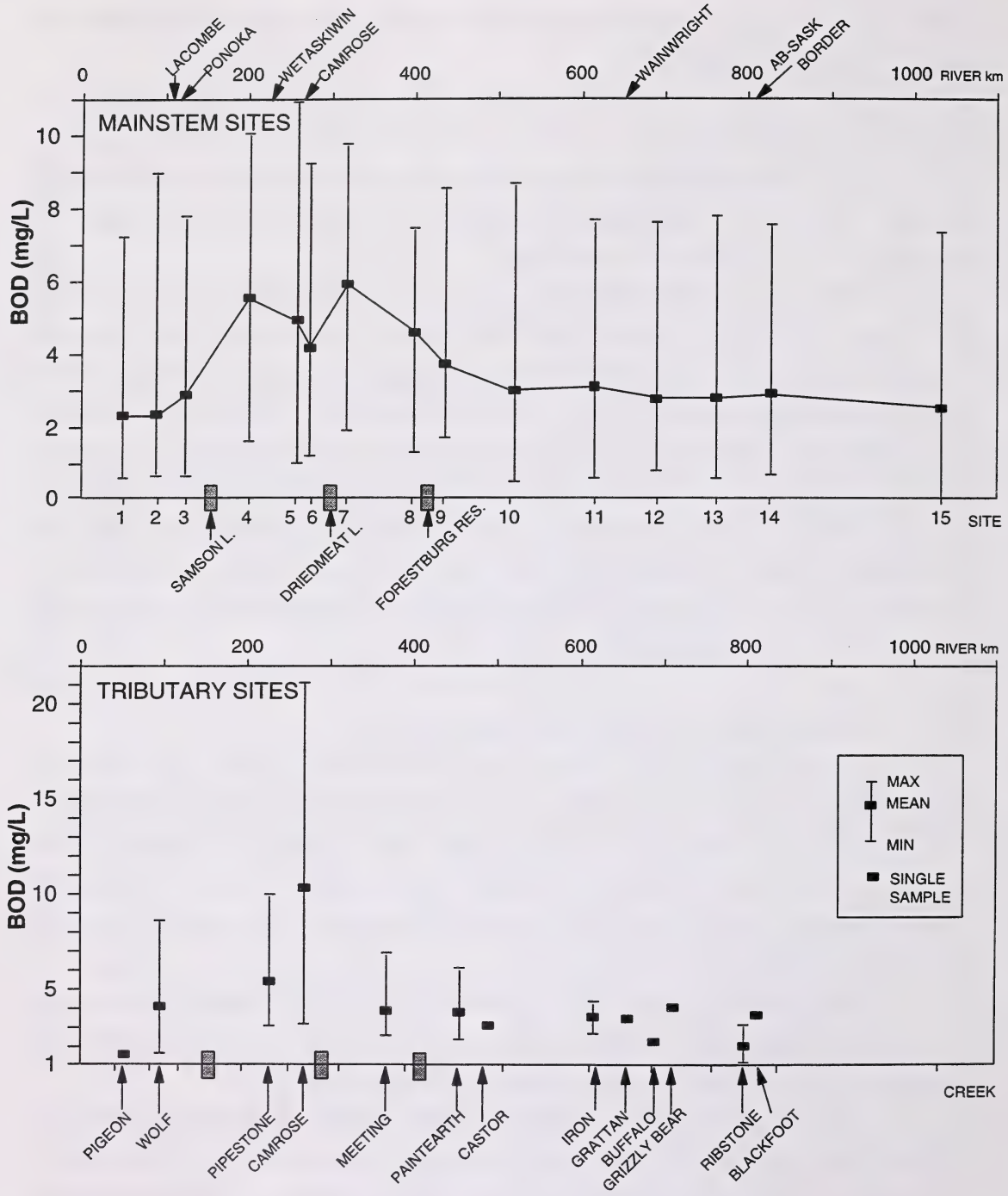


FIGURE 41. BOD in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

hypereutrophic bodies of water, and by tributaries such as Wolf, Pipestone and Camrose creeks which drain extensive agricultural areas and receive municipal wastewater from the largest municipalities in the basin. Although some of the higher BOD values recorded at Highway 21 and downstream of Camrose Creek coincide with municipal discharges from Wetaskiwin and Camrose (Appendix 2, April and October 1990 surveys), there is not always a simple relationship between in-stream BOD and BOD load from point and non-point sources since BOD is not a conservative variable. However, nutrients supplied by these sources promote the production of animal and especially plant biomass. Ultimately, the decomposition of this biomass inflates in-stream BOD.

In the Battle River at Unwin, DO was independent of river flow (Table 9) and showed no detectable long-term trend over the period of record (Table 10). However, there was a marked seasonal trend (Figure 42). Median dissolved oxygen concentrations were typically very low (<2 mg/L) under ice cover in January and February with extreme lows at or near 0 mg/L. Ice-melt, which usually occurs in March in the Unwin area, was associated with a climb in median DO level to 6 mg/L. However, the variability in DO levels in that month was large, as shown by the wide ranges for interquartile and extreme values. This large degree of variability was influenced by the timing of the water quality sampling in March relative to that of ice-melt. Median DO concentrations remained well above 8 mg/L from April to October. However, since DO levels at Unwin are only measured during the day, medians and ranges shown in Figure 42 may not be a true picture of the variability in DO levels. The effect of high water temperatures in reducing the solubility of oxygen was reflected in a decrease of median monthly DO concentrations during the summer. The lowest median DO values for the summer were recorded in July, the month with the warmest water temperature (Figure 14). Median DO concentrations were highest in November, but the degree of variability in that month and the drop in DO levels in December show that DO can be rapidly depleted under ice cover.

Diurnal fluctuations in DO at three sites in the Battle River are shown in Figure 43. Large diurnal fluctuations related to aerobic respiration and photosynthesis by algae and macrophytes were recorded at these three sites in August 1989. Fluctuations were largest at Highway 611 which had the most abundant stand of macrophytes. Typically, lowest DO levels were measured in the morning between 7 and 10 am, and highest DO levels in the early evening between 7 and 10 pm. Differences as large as 6 mg/L were recorded over a 24 hour cycle. In February 1991, diurnal fluctuations were not apparent at any of the three sites and DO levels varied by less than 0.5 mg/L. The Battle River downstream of Camrose Creek was anoxic at that time.

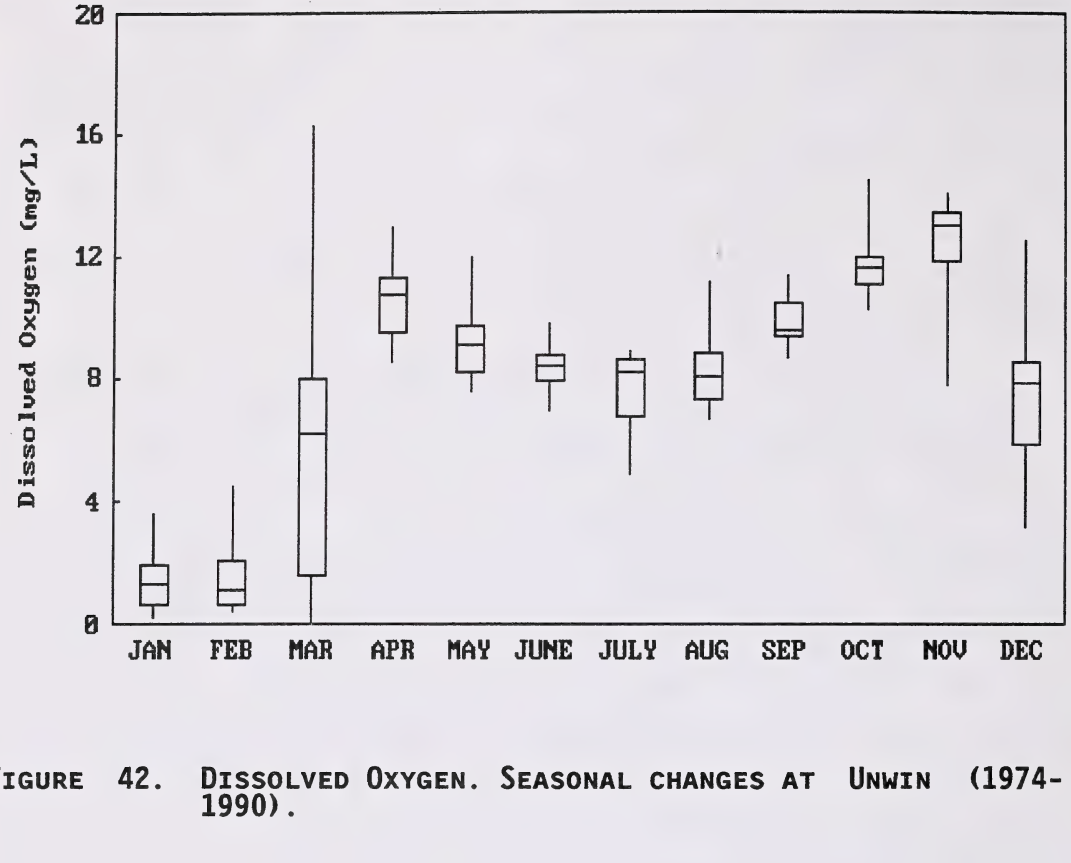


FIGURE 42. DISSOLVED OXYGEN. SEASONAL CHANGES AT UNWIN (1974-1990).

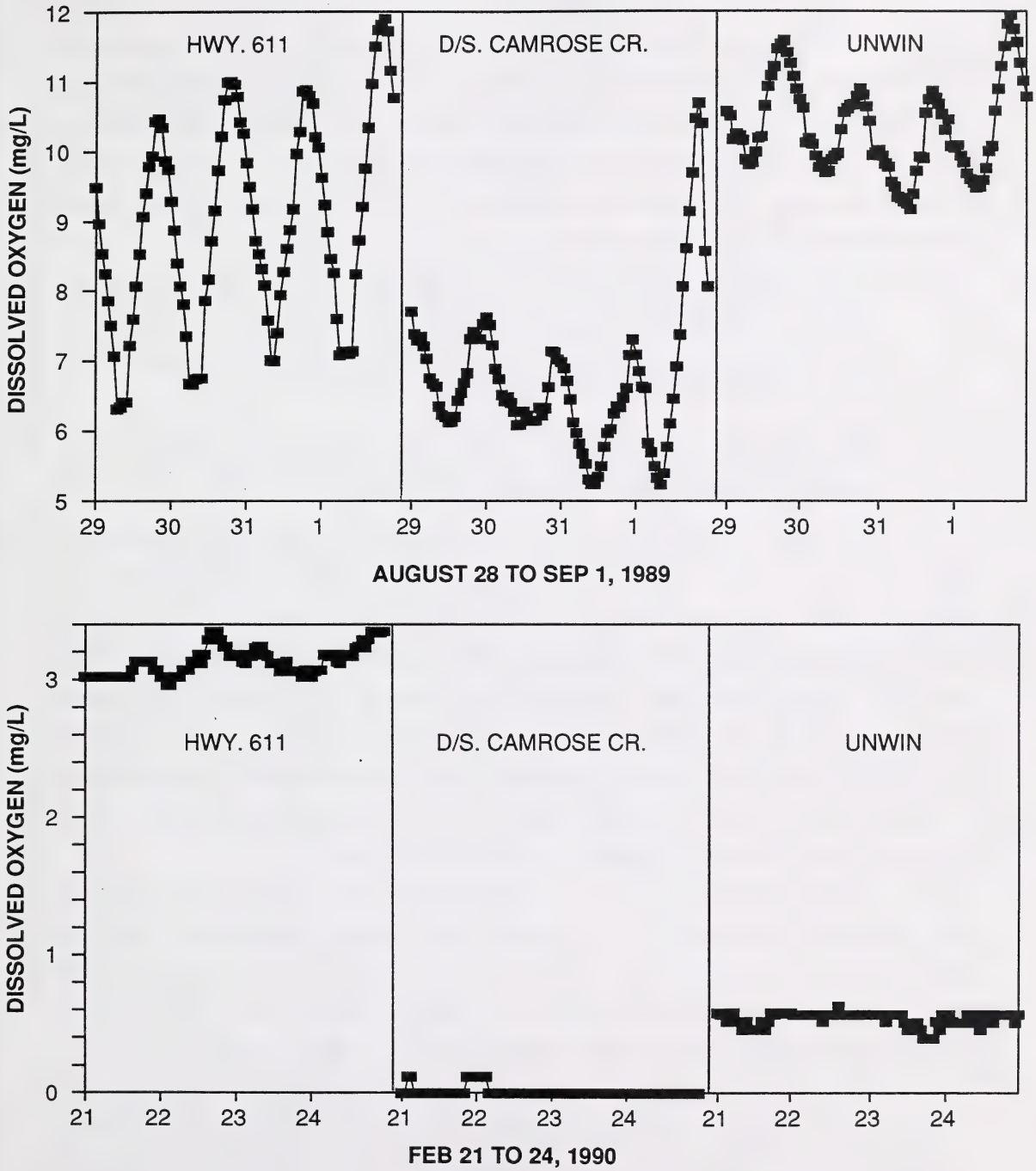


FIGURE 43. Diurnal fluctuations in dissolved oxygen levels at three sites on the Battle River (hourly Datasonde records).

Average DO levels in the Battle River for the 1989-1990 surveys ranged from 7.3 (Highway 611, site 1) to 9.9 (downstream Ponoka, site 3) (Figure 44). Low average DO levels were recorded in three stretches of the river: upstream, at site 1 and 2; at sites upstream and downstream of Driedmeat Lake (site 6 to 8); and in the lower part of the river at the Saskatchewan sites (site 14 and 15). Since most of the surveys were conducted during the open-water-period, average DO concentrations for these surveys may be biased and overestimate a true annual average based on more evenly distributed samplings. Diurnal fluctuations could also have influenced survey data:

1. Extremes recorded during the surveys generally correspond with winter minima and summer maxima, misleadingly conveying the impression that DO levels are high during the summer. Some data collected in the early part of the day suggest that very low DO levels may also occur during the summer. For example, the lowest DO record downstream of Driedmeat Lake (site 7: 1.9 mg/L DO) was made on August 24, 1989 at 9:45 am.

2. Site 1 and 2 were always sampled first and before 12:00 am. This schedule may have overemphasized the difference between the average DO for these two sites and the averages for sites further downstream which were sampled later in the day.

Low winter DO concentrations are a perennial problem for fisheries in the Battle River. Anoxic conditions in and downstream of Driedmeat Lake have been documented (Grant and Bramm 1979, Fernet et al. 1985) and fish kills have occurred during the winter (e.g., Mitchell and Prepas 1990). Attempts to raise winter DO levels by releasing water from Coal Lake have had limited success (Sloman 1984). Winter survey data from 1989-1990 (Figure 45) conformed with longitudinal patterns described in earlier studies, especially with regard to oxygen depletion downstream of Driedmeat Lake, re-oxygenation in the open water in and downstream of the Forestburg Reservoir and depletion of DO under ice-cover in the lower portion of the river. Low DO concentrations in the upper portion of the river were not documented previously, because sampling was not conducted as far upstream.

Depletion of DO under ice cover is a natural phenomenon in some rivers. Babin and Trew (1985) documented the rapid depletion of DO in a stretch of the Beaver River which was not influenced by anthropogenic inputs. In the Battle River, which has many hydrological features in common with the Beaver River, it is probable that low winter DO levels are natural for most of the river. However, cultural eutrophication has undoubtedly exacerbated the problem.

There are no surface water quality guidelines for BOD levels, but BOD together with suspended solids are the only two effluent characteristics that municipalities with discontinuous discharges are required by licence to monitor once during their discharge. AASWQIG specify that DO levels should not drop below 5 mg/L; CCREM (1987) recommend DO levels not lower than 5 mg/L for the protection of the least sensitive stages of warm-water biota. DO requirements for sensitive stages of cold-water biota are

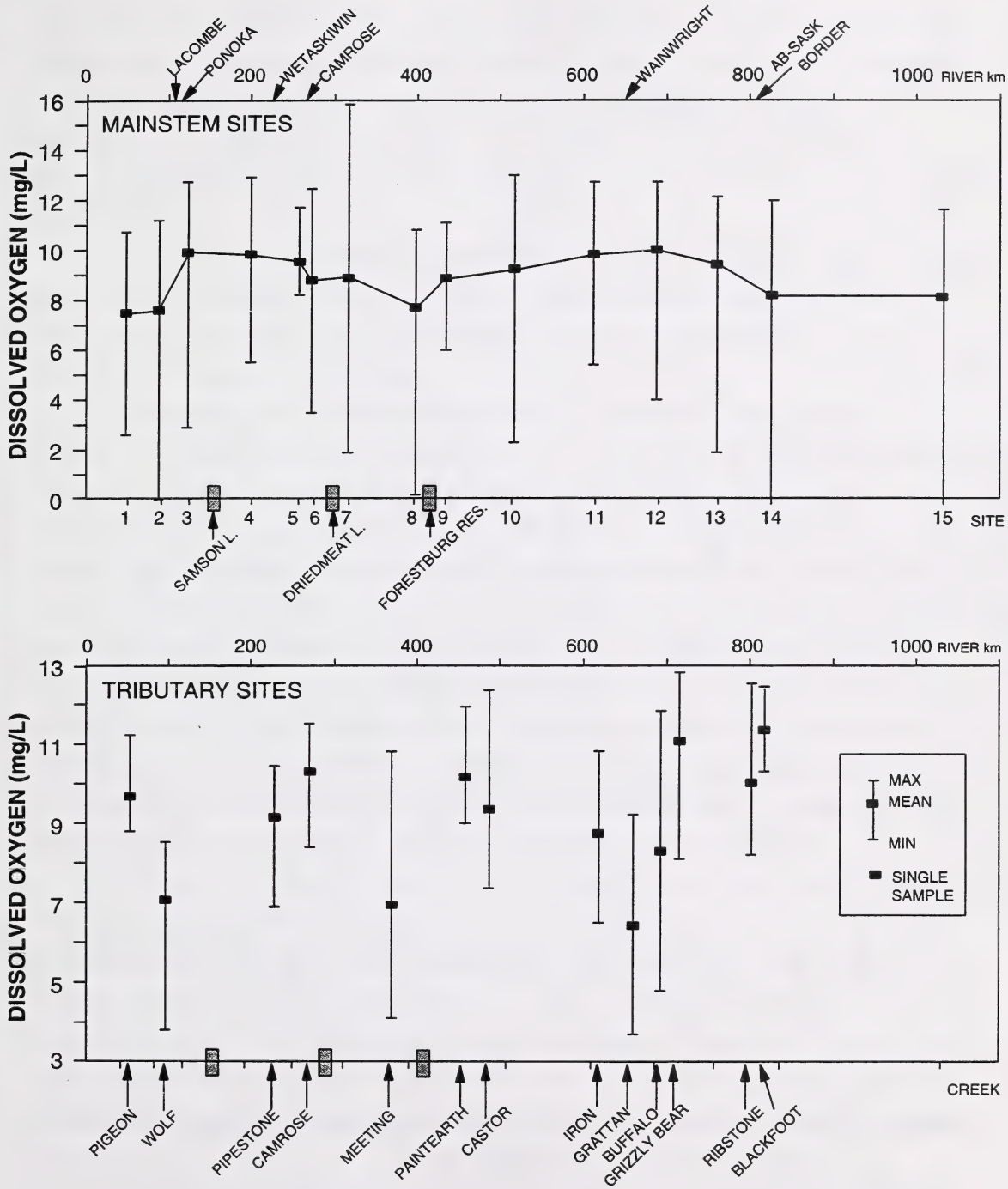


FIGURE 44. DISSOLVED OXYGEN in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

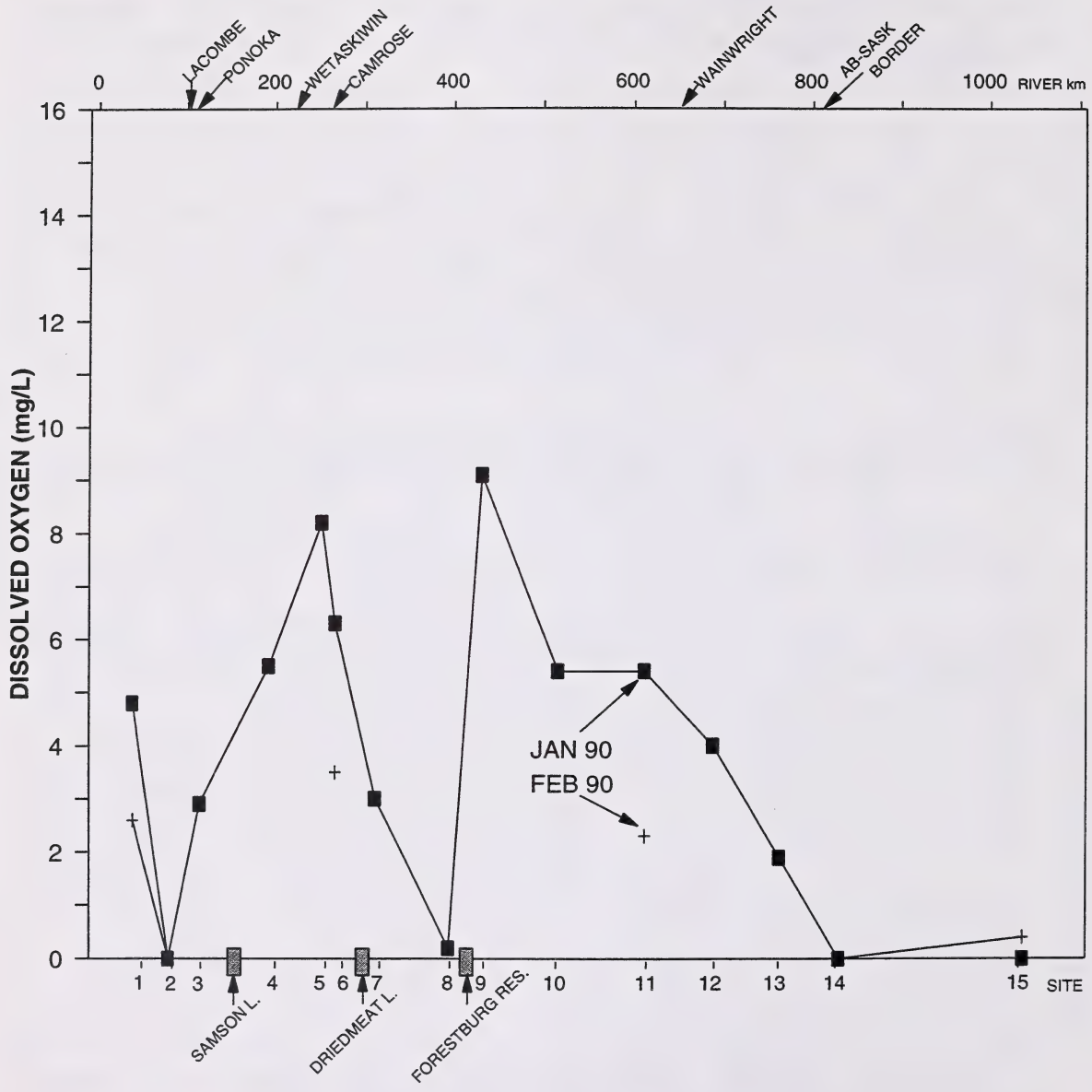


FIGURE 45. DISSOLVED OXYGEN - longitudinal changes recorded during winter surveys in the Battle River.

considered to be much higher. PPWB recommend 6 mg/L DO for the protection of fisheries. These guidelines or objectives are generally not met in the Battle River during the winter and they are unlikely to be met on an intermittent basis at most sites during the open-water period because of diurnal cycling.

4.3.4 Nutrients

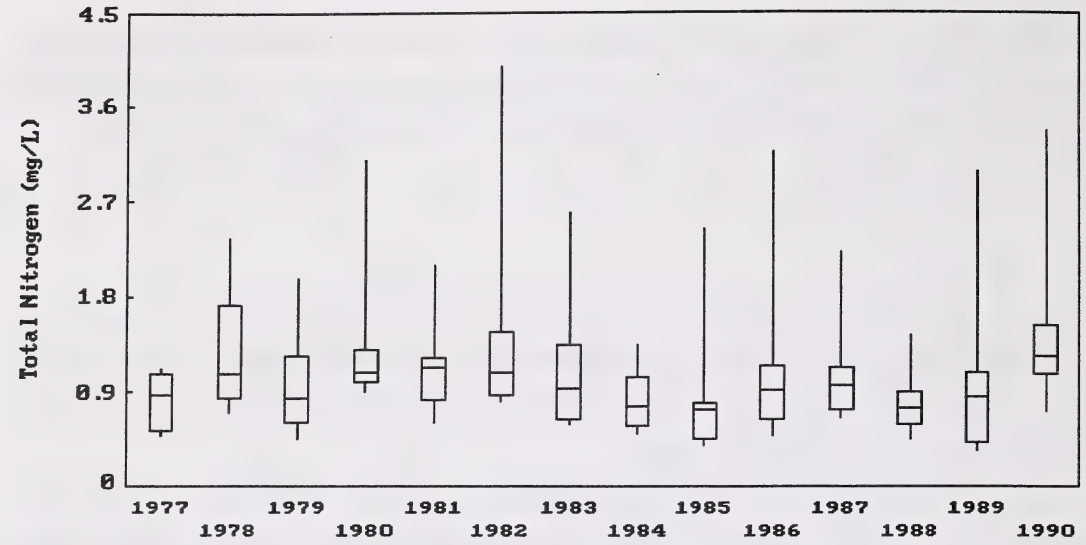
4.3.4.1 Nitrogen

Nitrogen occurs in inorganic and organic forms in aquatic environments. Inorganic forms include dissolved nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_3) and molecular nitrogen (N_2); organic forms include proteins, amino acids, urea, and methylamines, which may be encountered in dissolved or particulate form in dead or live organic matter.

The nitrogen cycle is a complex biogeochemical cycle which controls transformation processes among the various forms of nitrogen (e.g., Hutchinson 1957, CCREM 1987). Some blue-green algae and bacteria have the ability to convert molecular nitrogen to ammonia (biological nitrogen fixation) which is directly incorporated into organic nitrogen compounds. Through a process called ammonification, bacteria and fungi break organic nitrogen down to ammonia. Other micro-organisms can oxidize ammonia to nitrite and nitrate (nitrification); still others can reduce nitrate (denitrification). Plants can assimilate inorganic forms of nitrogen, such as nitrate and ammonia, and form organic nitrogen compounds. Heterotrophic conversion of organic nitrogen can occur along the food chain. The addition of nitrogen to aquatic systems can greatly enhance the growth of aquatic vegetation. Natural sources include the atmosphere, rain, snow and surface runoff. Municipal and industrial wastewaters are the principal anthropogenic point sources; non-point sources include runoff from forested areas, from agricultural land where nitrogen fertilizers are used, and runoff from intensive livestock operations including pasture land (CCREM 1987).

Nitrogen forms suitable for trend analysis in the long-term data at Unwin were total nitrogen (TN), dissolved nitrogen (DN), and (nitrate+nitrite) nitrogen. Concentrations of TN increased with increasing river discharge, but DN and (nitrate+nitrite) N were independent of flow (Table 9). A significant decline of 0.02 mg/L.yr TN and 0.01 mg/L.yr DN was detected over the period of record (Table 10, Figure 46). These changes are small on an annual basis, but over a 10 year period they represent a decline of nearly 20% and 15% of the median annual total and dissolved nitrogen, respectively. The decline in total nitrogen is apparently related to that of dissolved nitrogen, but the cause of the changes is unknown.

Seasonal changes for TN were related to hydrological changes in the river and were typified by low median concentrations (about 0.80 mg/L TN) in the winter, and high median values (about 2 mg/L TN)



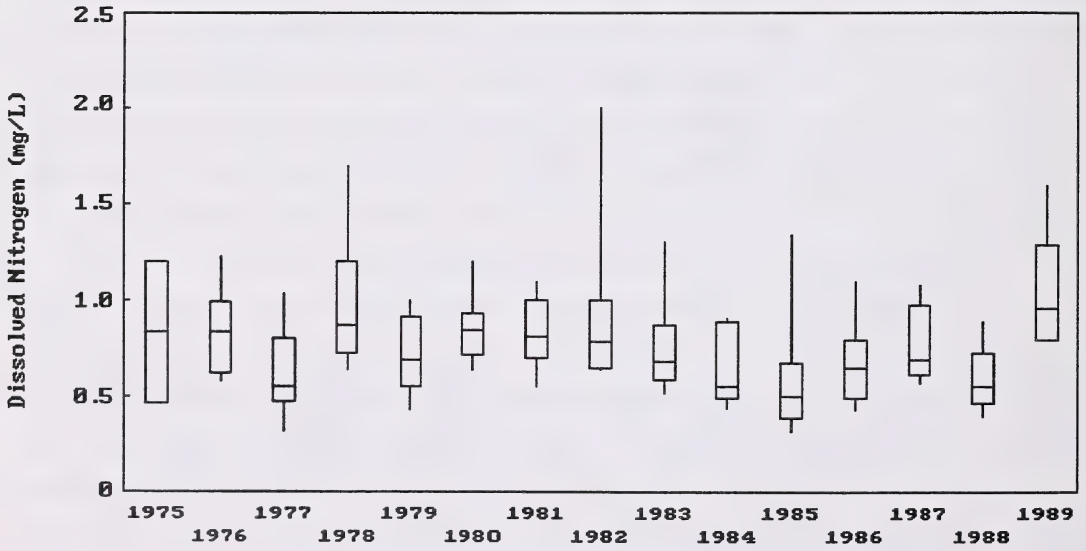


FIGURE 46. TOTAL AND DISSOLVED NITROGEN. YEAR-TO-YEAR CHANGES AT UNWIN.

at spring runoff time (Figure 47). In contrast, highest median (nitrate+nitrite) N concentrations were recorded from December to April (approximately 0.3 mg/L) whereas lowest median values, at or near the detection limit, typified most of the open water period (Figure 47). This pattern reflects seasonal changes in algal and macrophytic utilization.

Longitudinal and seasonal changes in nitrogen forms recorded during the 1989-1990 surveys are summarized in Figure 48 to 54 and shown in Appendix 1.

Total Kjeldahl nitrogen (TKN) is a joint measure of organic nitrogen and ammonia. It was the most abundant form of nitrogen in the Battle River (Figure 48), with average concentrations for 1989-1990 ranging from 0.83 mg/L (at site 1, Highway 611) to 2.33 mg/L (at site 7, downstream Driedmeat Lake). In all surveys, except those conducted in early spring (early May 1989, April 30) most of the TKN was in dissolved form (Appendix 1). The high proportion of particulate Kjeldahl nitrogen during spring runoff reflects the downstream transport of organic material that settles over the winter on the river bottom or that enters the stream with surface runoff. Highest TKN concentrations were usually recorded at spring runoff time although the maximum (5.4 mg/L) was recorded in fall downstream of Driedmeat Lake.

In 1989-1990, average concentrations of dissolved inorganic nitrogen were of the order of 0.1 mg/L nitrate+nitrite, 0.01 mg/L nitrite and 0.1 mg/L ammonia (Figures 49 to 51). The highest average ammonia levels occurred downstream of Camrose Creek (site 6) and downstream of Driedmeat Lake (site 7), whereas the highest average nitrate and nitrite levels occurred downstream of the Forestburg Reservoir (site 9 and site 10). Nitrate, nitrite and ammonia levels were generally high during the winter and in early spring at runoff time, but concentrations were low during the latter part of spring, summer and most of the early fall (Figure 52 to 54). This seasonal pattern, already described for the long-term data at Unwin, is not unusual for small rivers or streams in Alberta and it has been documented in detail for some streams which flow into Baptiste Lake (Trew et al. 1987).

The large on-stream lakes and municipal discharges to the Battle River influence the longitudinal profile of dissolved inorganic nitrogen and explain some deviations from the seasonal pattern. For example, the very high ammonia levels measured in October 1989 downstream of Driedmeat Lake (site 7) (Figure 54) likely resulted from the decomposition of macrophytes and algae originating in-stream and in Driedmeat Lake.

In the winter survey, (NO_3+NO_2)-N levels increased by nearly an order of magnitude downstream of the Forestburg Reservoir (Figure 52). This indicates that nitrification processes are important in the reservoir, which remains at least partly ice-free and well oxygenated during most of the

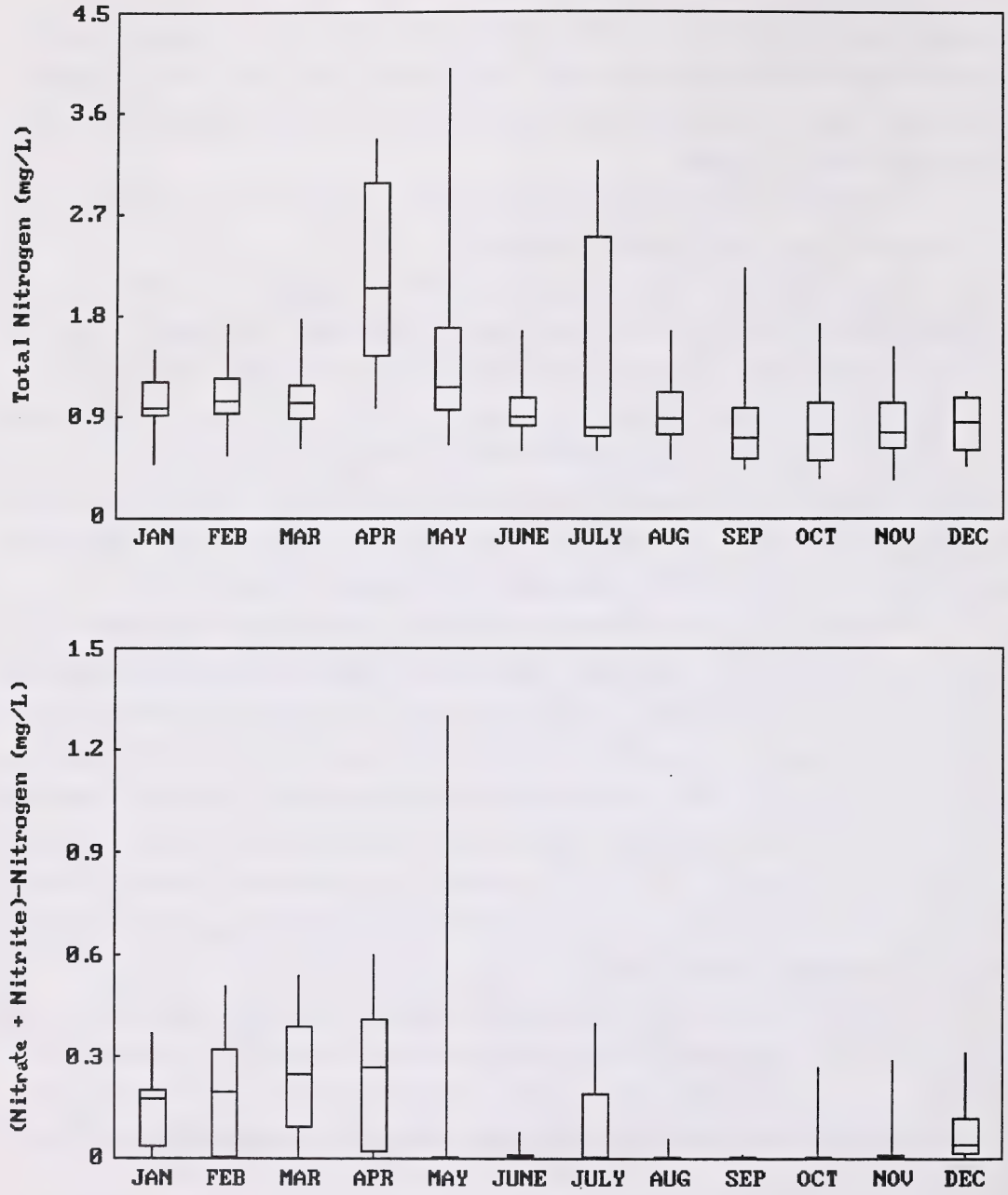


FIGURE 47. TOTAL NITROGEN AND (NITRITE+NITRATE)-NITROGEN, SEASONAL CHANGES AT UNWIN (1974 OR 1977-1990).

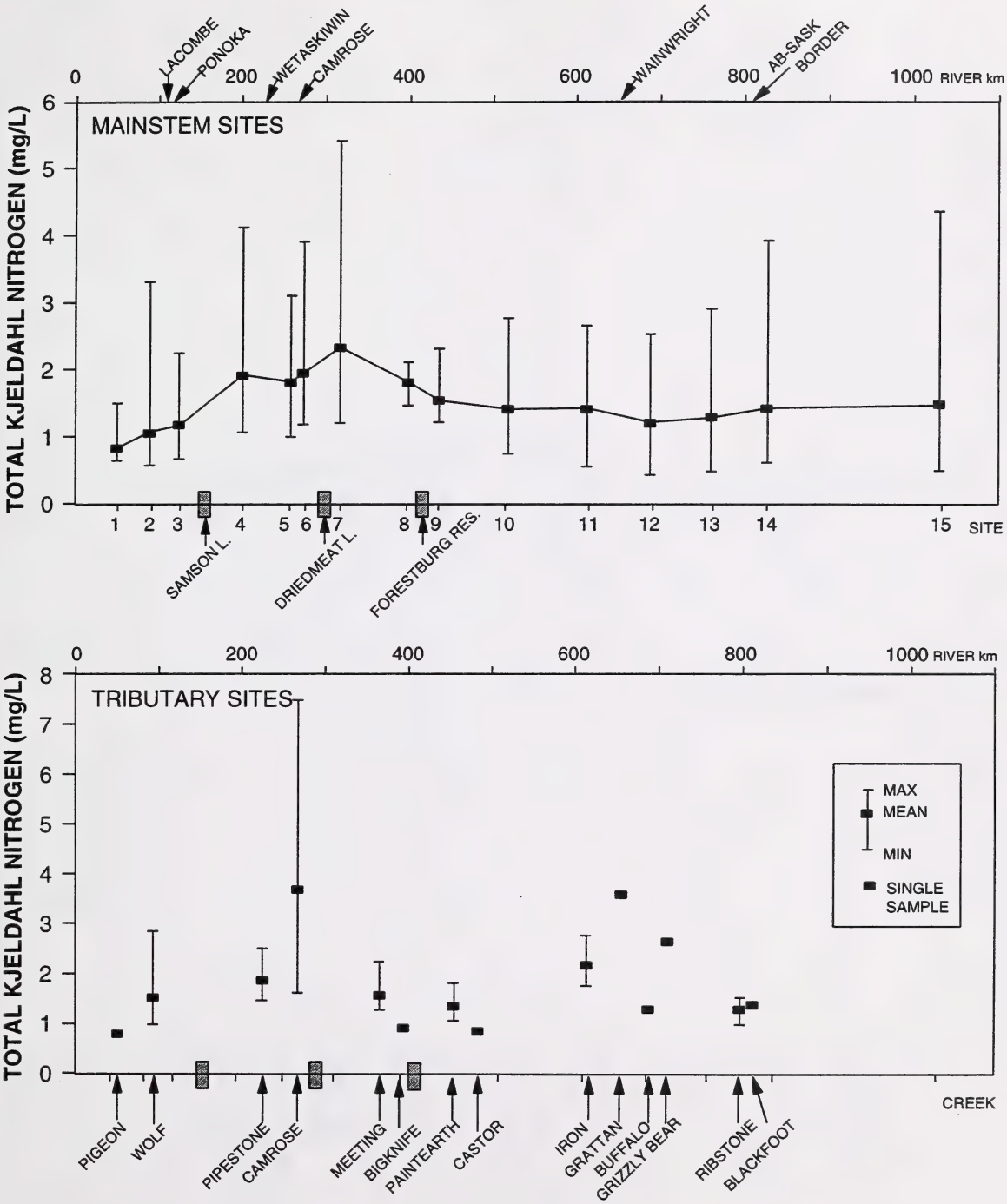


FIGURE 48. TOTAL KJELDAHL NITROGEN in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

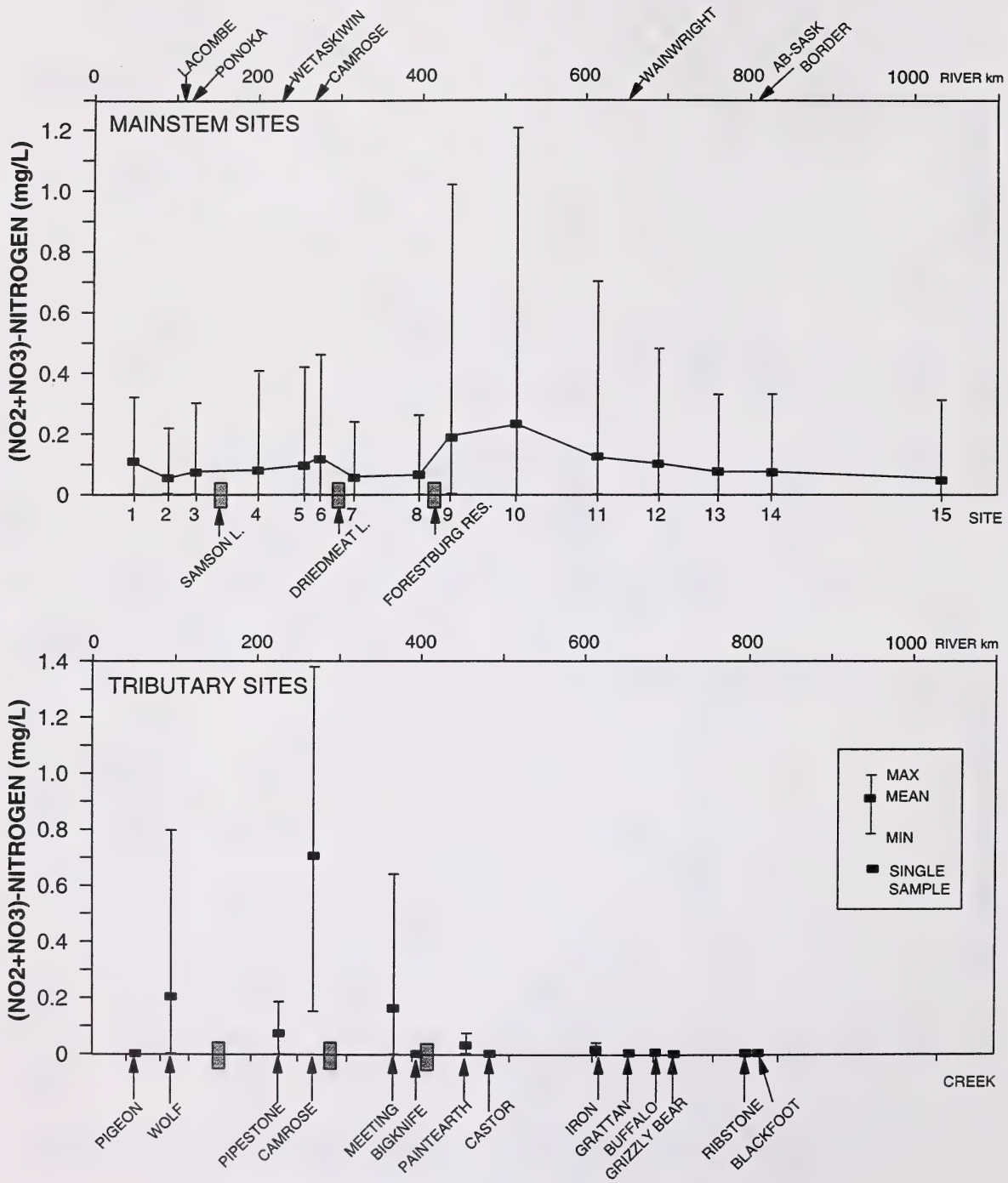


FIGURE 49. (NO2+NO3)-NITROGEN in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

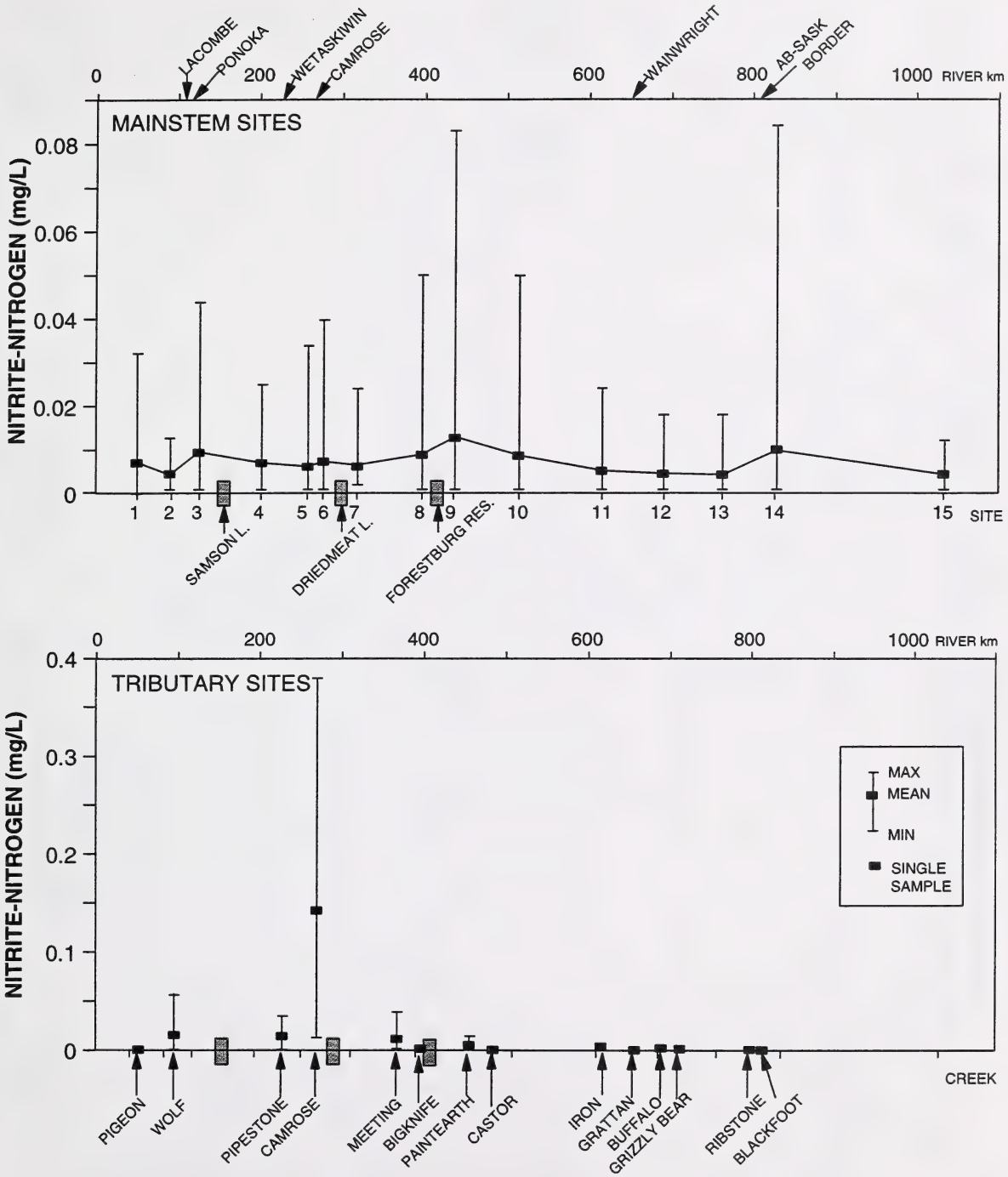


FIGURE 50. NITRITE-NITROGEN in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

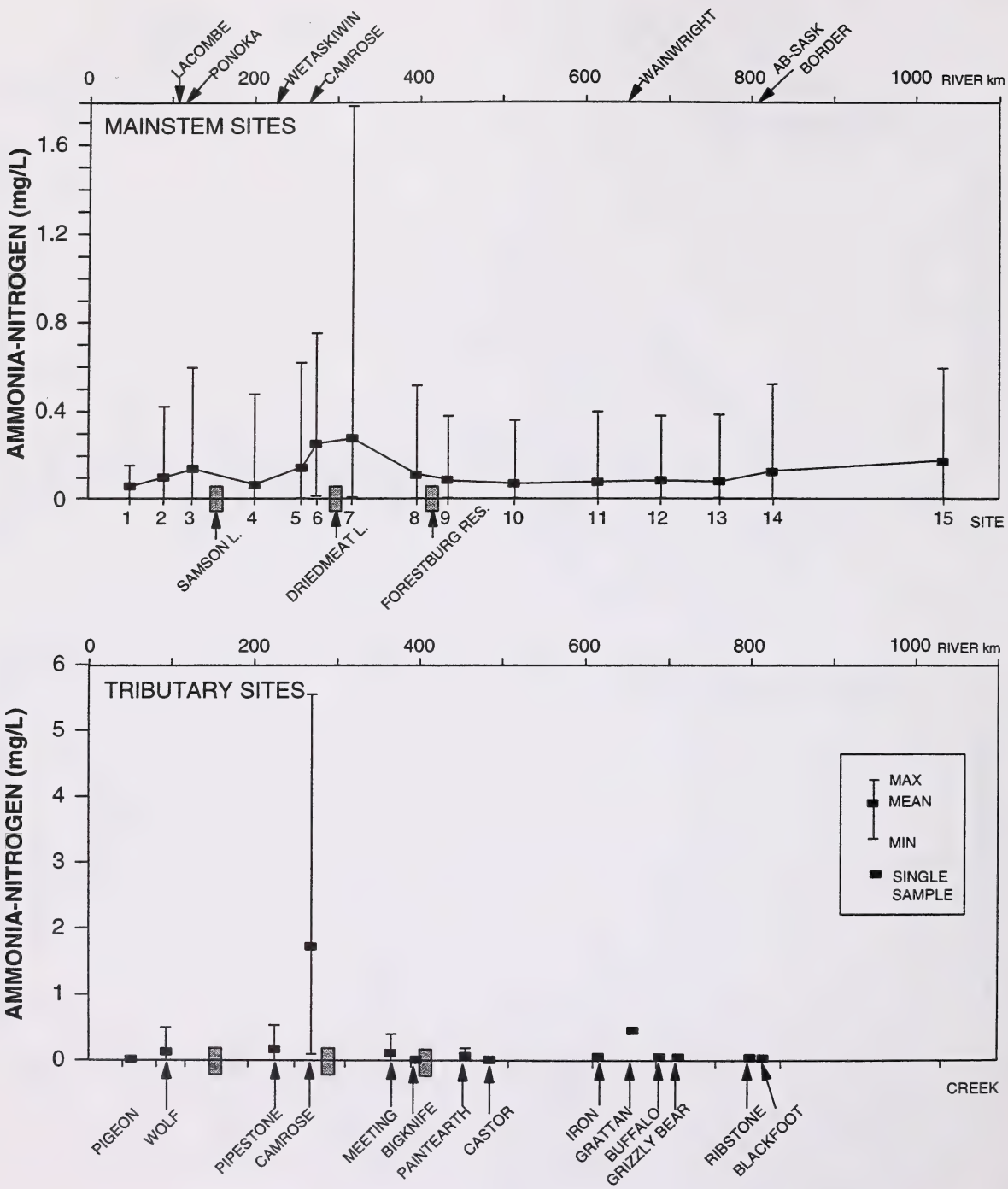


FIGURE 51. AMMONIA-NITROGEN in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

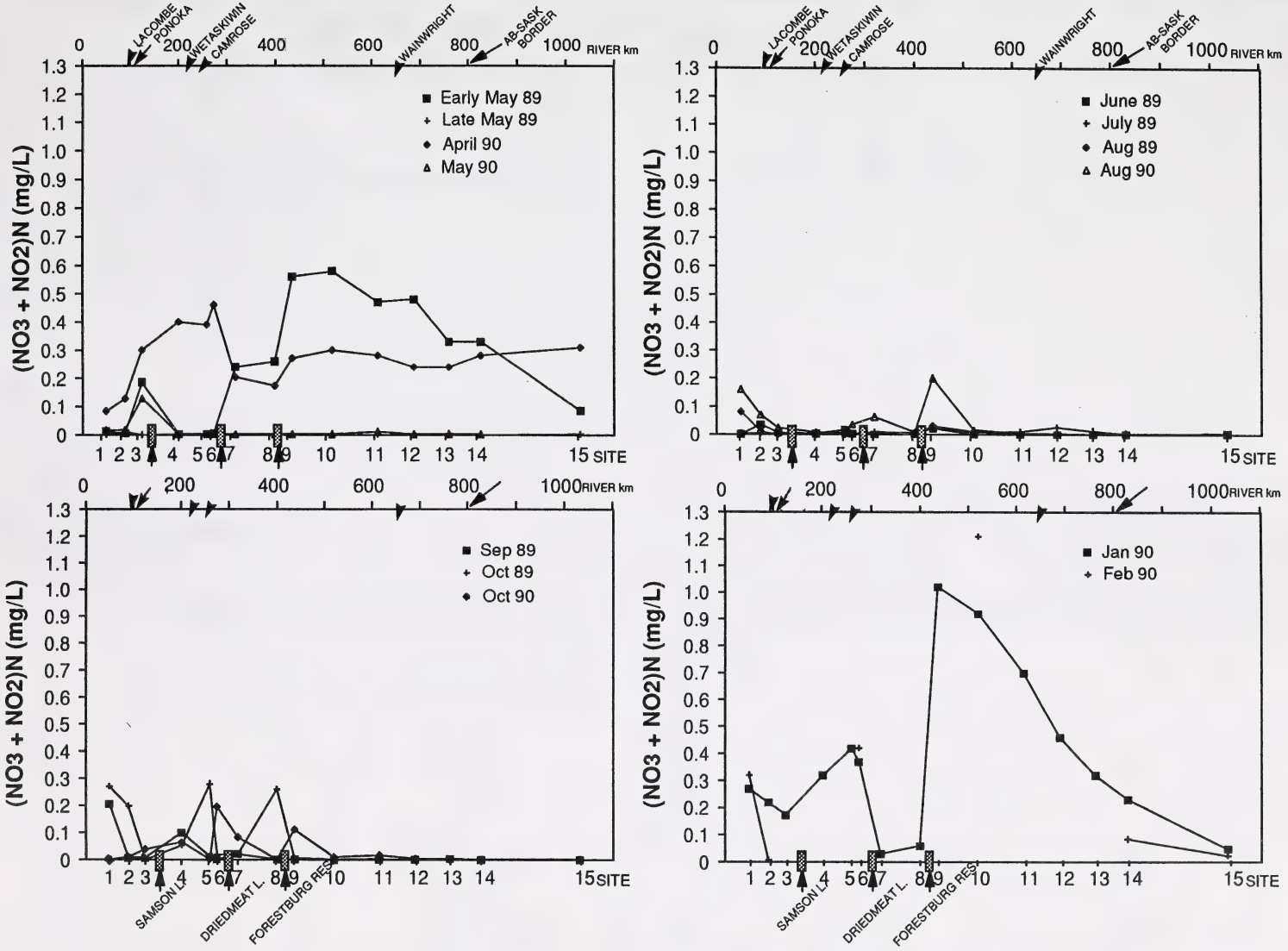


FIGURE 52. (NITRATE + NITRITE)-NITROGEN - longitudinal changes recorded during seasonal surveys (1989 - 1990).

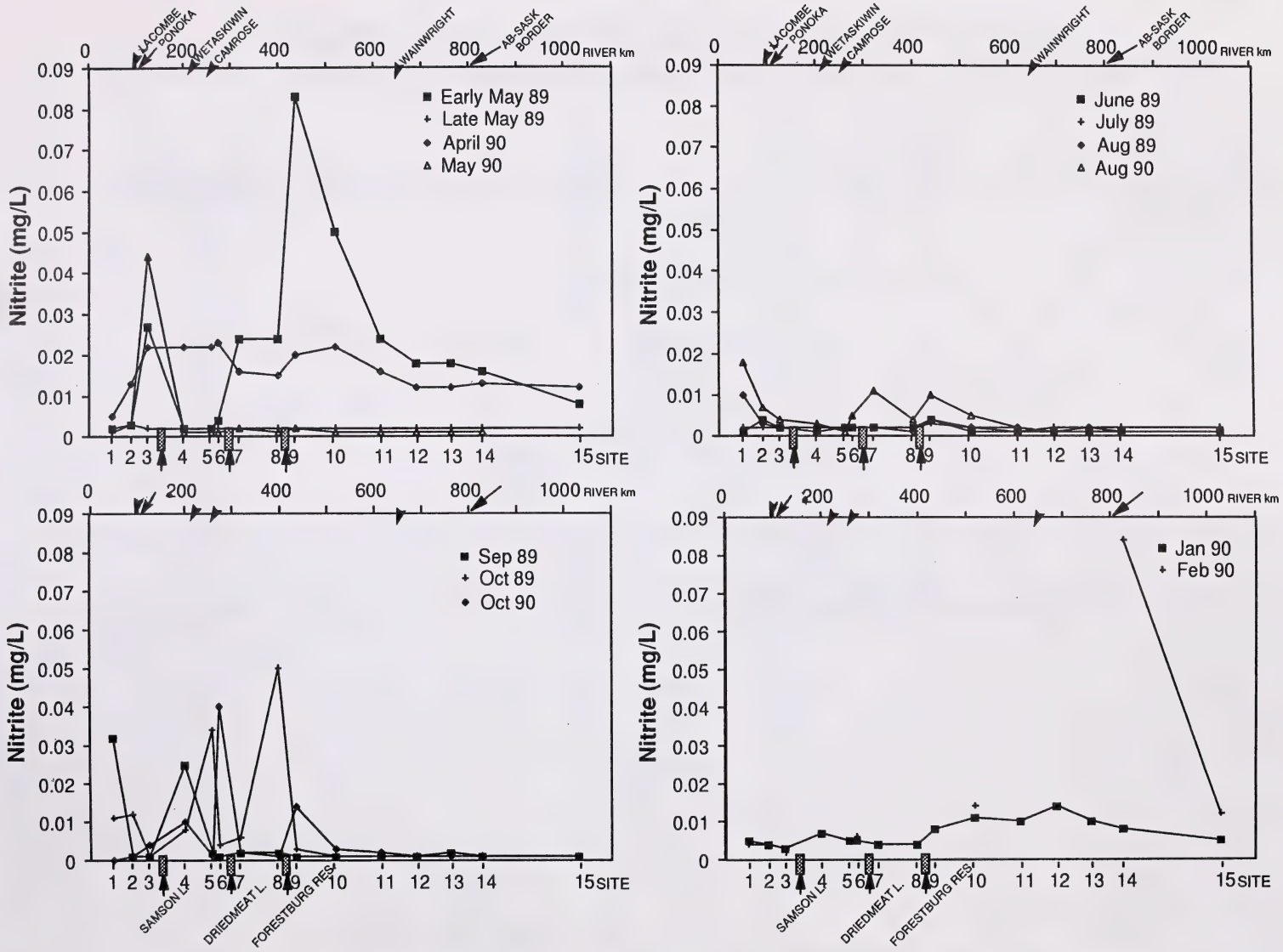


FIGURE 53. NITRITE NITROGEN - longitudinal changes recorded during during Seasonal surveys (1989 - 1990).

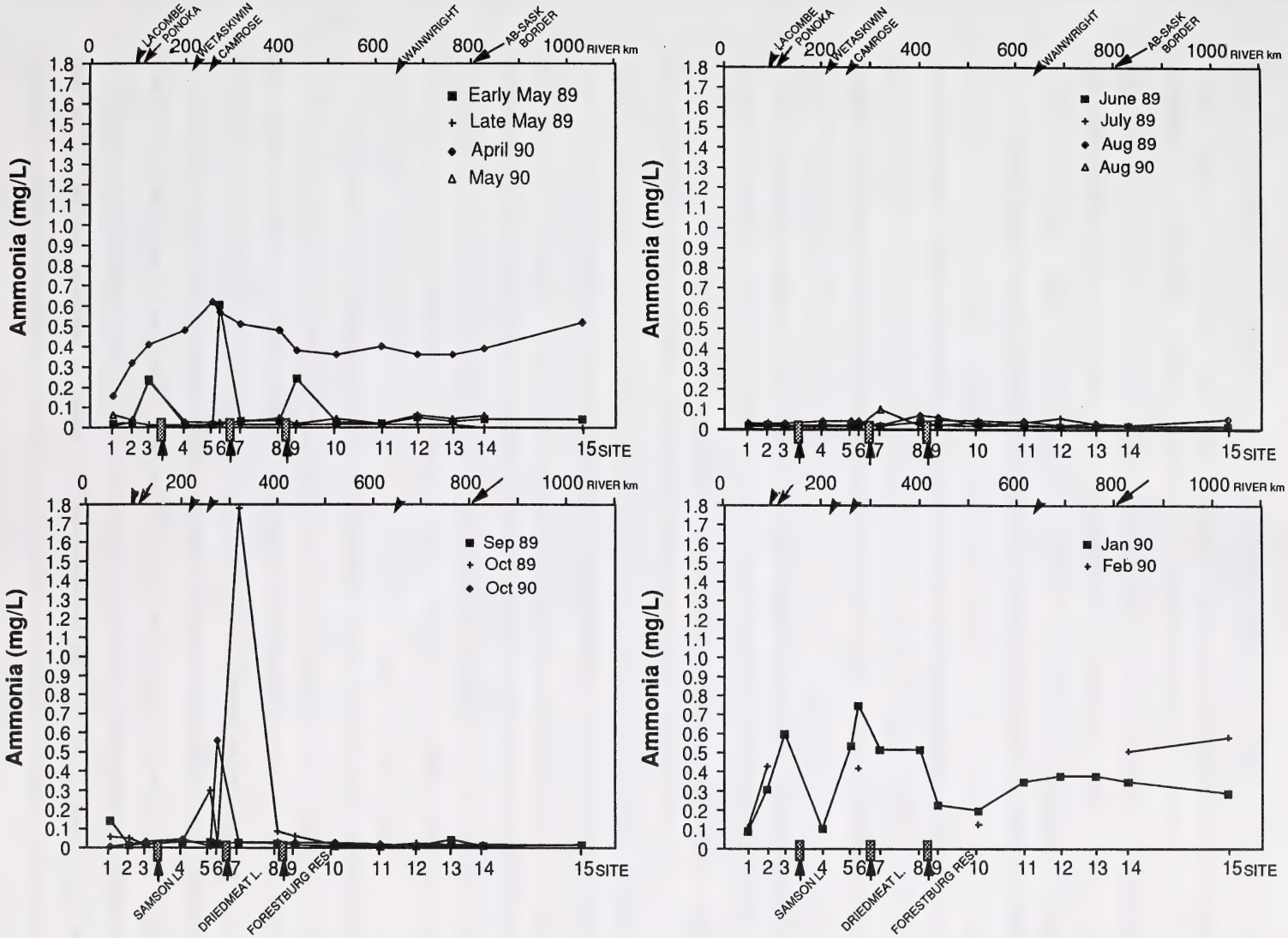


FIGURE 54. AMMONIA-NITROGEN - longitudinal changes recorded during seasonal surveys (1989 - 1990).

winter. Winter data for 1990 suggest that denitrification may occur further downstream as DO concentrations become depleted under ice cover (Figures 45, 52, 54).

The effect of municipal discharges on in-stream nitrogen concentrations is reflected in concentration peaks at several sites in the western portion of the basin. More specifically, concentration peaks for nitrate, nitrite and ammonia observed at site 3 and 6 in spring coincide with the municipal discharges from Lacombe (1989), Ponoka (1990) and Camrose (1989), whereas concentration peaks at site 5 and 6 in fall coincide with discharges from Wetaskiwin (1989) and Camrose (1990) (Figure 2, 52, 53, 54).

Tributaries in the western portion of the basin tend to have higher average concentrations of most forms of nitrogen than tributaries in the east (Figures 49 to 51) and they also contribute more to average in-stream loads (section 4.1.3). Very high concentrations measured in Camrose Creek coincide with fall discharges from Camrose. There is little question that municipal discharges account for a significant portion of the nitrogen loads in these tributaries. However, because nitrogen does not behave as a conservative element it is difficult to compare the relative contribution from point-sources (i.e., municipal discharges) and non-point sources (i.e., surface runoff) with the data available.

AASWQIG specify that TN should not exceed 1 mg/L. In 1989-1990 these objectives were exceeded by average TN concentrations at all sites except Highway 611 (site 1) and on one or more occasions by single measurements at all sites, including most tributaries.

CCREM (1987) recommends that levels of nitrite not exceed 0.06 mg/L. These guidelines were exceeded by single measurements at site 9 (May 3, 1989) and at site 14 (February 9, 1990) in the Battle River and twice in Camrose Creek during or shortly after the discharge of wastewater (May 22, 1990 and October 9, 1990).

In water, un-ionized ammonia (NH_3) exists in equilibrium with the ionized form (NH_4^+). The un-ionized form is toxic to fish and other aquatic life at very low concentrations. The concentrations of un-ionized ammonia and its toxicity depend on pH, temperature, and the total ammonia concentration. CWQG apply to total ammonia and reflect both of these variations. Based on pH and temperature records at the time of sampling, ammonia levels in the Battle River complied with CWQG most of the time. However, ammonia levels were close to the maximum recommended levels on several occasions (e.g., downstream of Driedmeat Lake, and at most sites in the April 1990 survey). There were some notable cases where concentrations exceeded guidelines. In April 1990 ammonia levels exceeded guidelines in Pipestone Creek and in Camrose Creek and at the Battle River site immediately below the confluence with these creeks (i.e., site 5 and 6). In October 1990 ammonia levels were far in excess of recommended guidelines in Camrose

Creek as well as in the Battle River downstream of Camrose Creek. In each instance, excessive ammonia levels in the Battle River and the two creeks coincided with municipal discharges from Wetaskiwin and/or Camrose.

4.3.4.2 Phosphorus

Phosphorus, an essential macro-nutrient (Wetzel 1983, CCREM 1987), occurs in various organic and inorganic forms which may be measured as dissolved or particulate phosphorus. Among the particulate forms, Wetzel (1983) includes phosphorus in organisms, mineral phases of rock and soil in which phosphorus is adsorbed onto inorganic complexes such as clays, carbonates and ferric hydroxides, phosphorus absorbed onto dead particulate organic matter or in mass aggregations. Dissolved phosphorus is composed of orthophosphate, polyphosphate, organic colloids or phosphorus combined with absorptive colloids and phosphate esters.

Phosphorus cycling in natural waters is influenced by exchanges between sediments and water. In turn the exchange mechanism is influenced by mineral-water equilibria, sorption, redox interactions and biological activity (CCREM 1987; Wetzel 1983). Natural sources of phosphorus include leaching and weathering of rock, decomposition of organic matter, atmospheric deposition and soil erosion. Anthropogenic sources are mainly domestic and industrial effluents and drainage from fertilized land.

Total phosphorus (TP) at Unwin was positively correlated with river discharge (Table 9): highest median concentrations coincided with peak flows in April and lowest concentrations occurred at winter low flows under ice cover (Figure 55). The highest monthly median dissolved phosphorus (DP) concentrations were also detected at peak flow, but correlation of DP with river discharge was weak (Table 9, Figure 55). No significant change in median concentrations was detected for TP or DP at Unwin over the period of record (Table 10).

In 1989-1990 average TP concentrations ranged from 0.081 mg/L at site 1 (Highway 611) to 0.372 mg/L at site 7 (downstream Driedmeat Lake); average concentrations in the eastern portion of the basin were within the range of 0.1 to 0.2 mg/L TP (Figure 56). Maxima were usually recorded at spring runoff. They increased in a downstream direction and reflected the relationship between flow and river discharge. At spring runoff time most of the TP was in particulate form (Figure 57), which suggests that most of the phosphorus was associated with sediment, soil or particulate organic matter. The TP concentrations at that time reflect in-stream transport of bed load material and contributions from surface runoff.

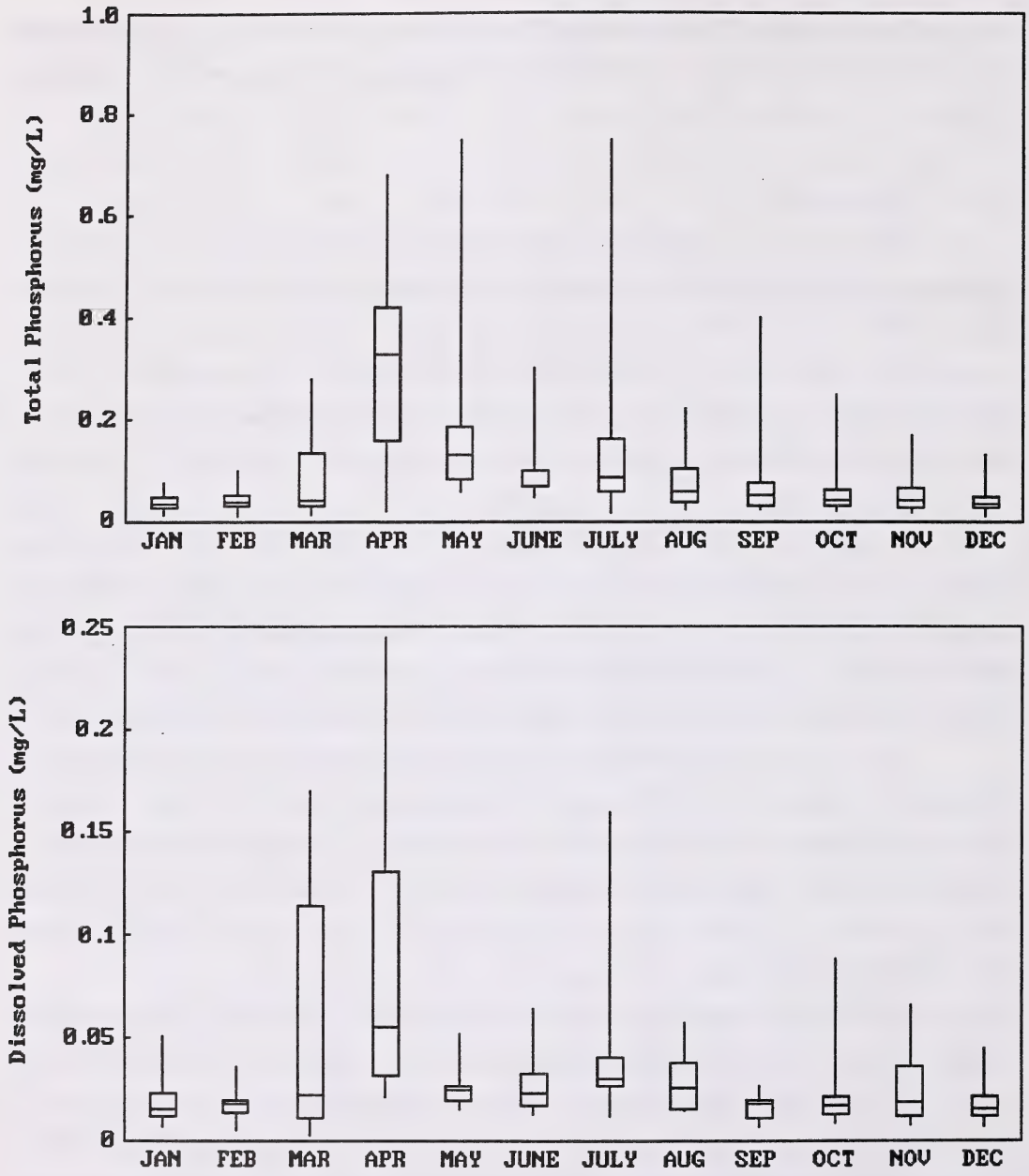


FIGURE 55. TOTAL AND DISSOLVED PHOSPHORUS SEASONAL CHANGES AT UNWIN (1974 - 1990).

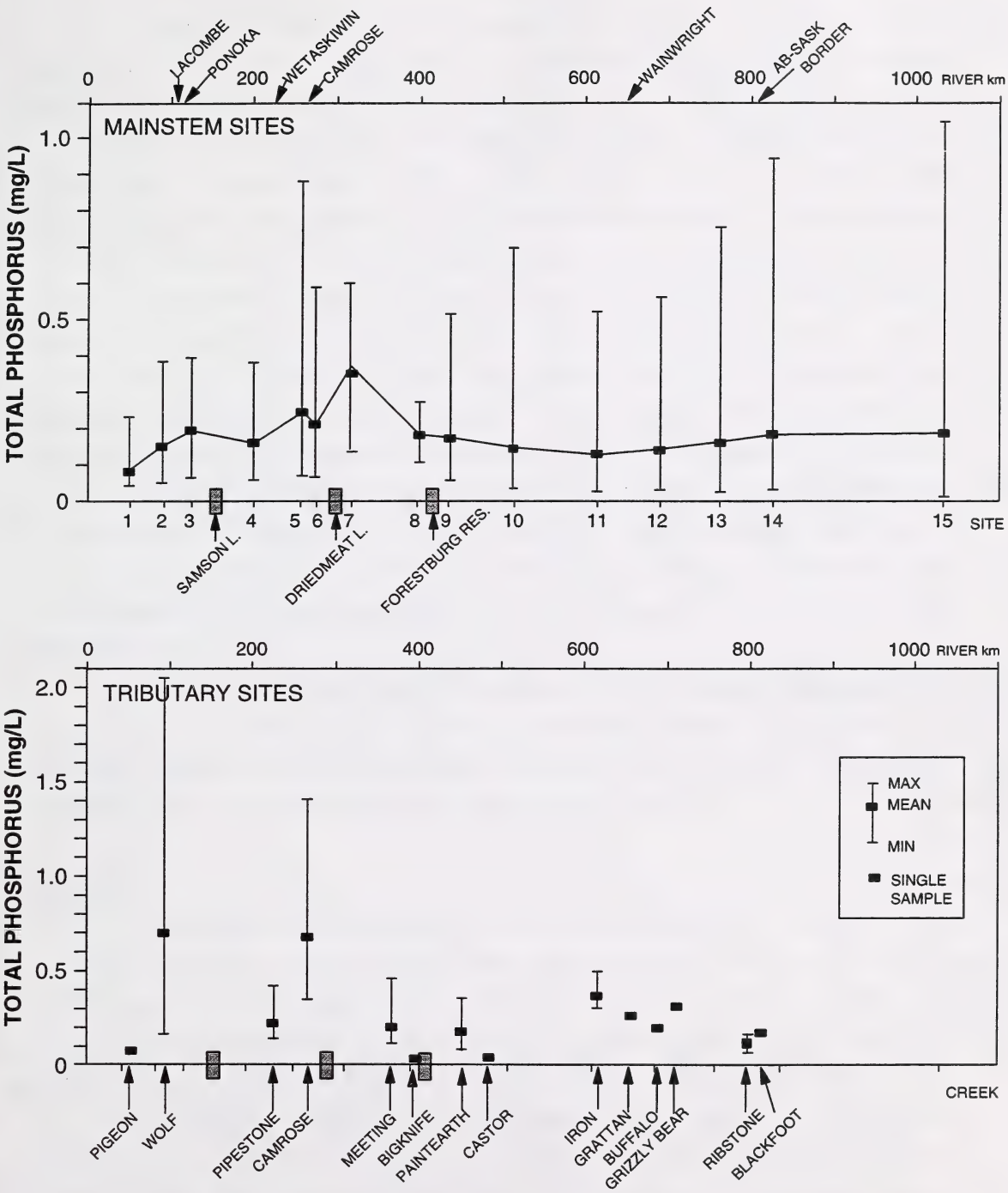


FIGURE 56. TOTAL PHOSPHORUS in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

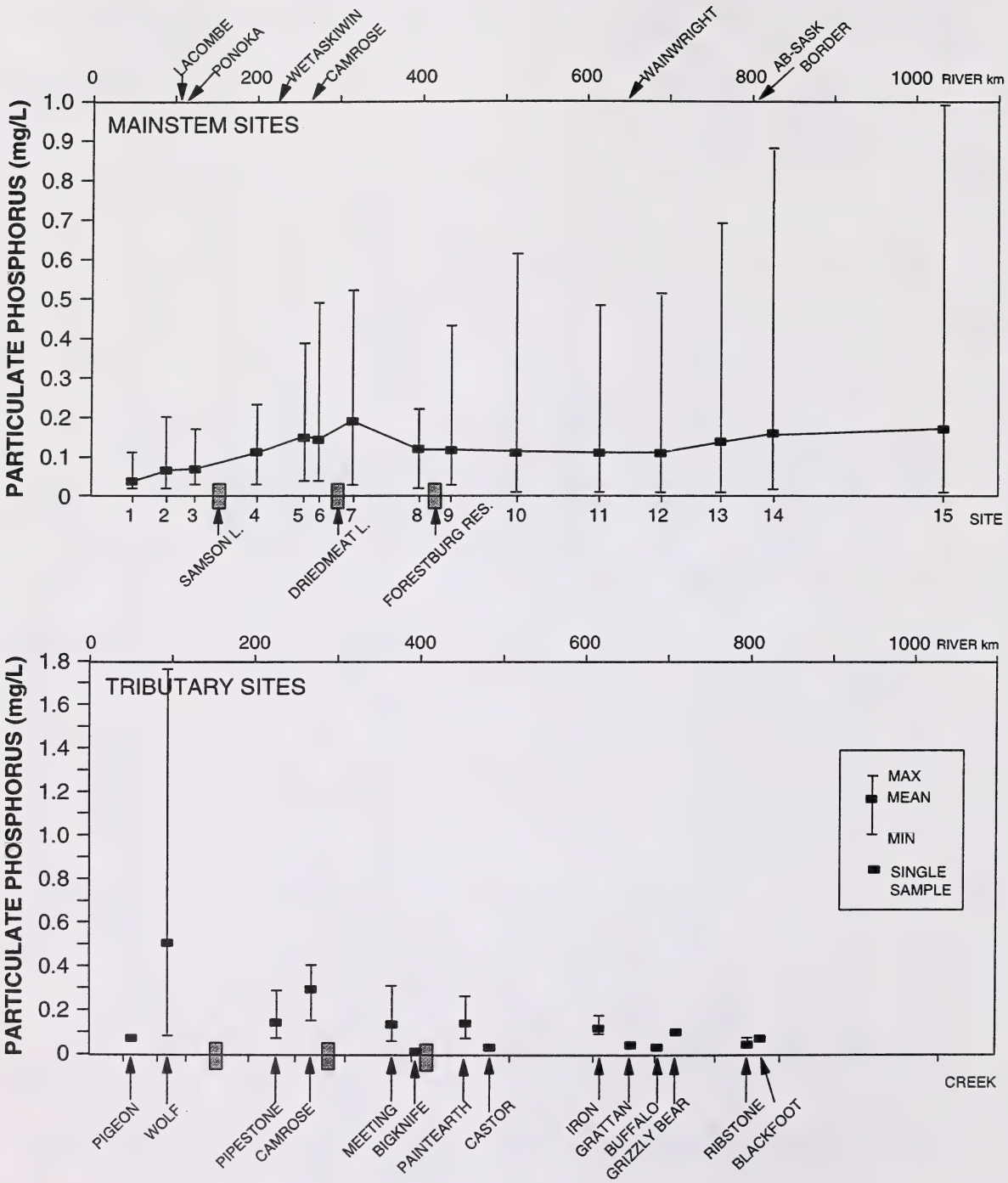


FIGURE 57. PARTICULATE PHOSPHORUS in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

Some of the maxima recorded in the western portion of the basin coincide with the discharge of municipal effluent. More specifically, the TP increase at site 3 (Figure 58) coincided with or followed the discharge from Lacombe (early May 1989), and Ponoka (May 1990), whereas the increase recorded at site 6 coincided with the discharge from Camrose (early May 1989) and that at site 5 coincided with the discharge from Wetaskiwin (October 1990). A similar synchronism was noted between municipal discharges and tributary concentrations: TP maxima in Wolf Creek and Camrose Creek coincided with wastewater discharges from Lacombe (May 1990) and Camrose (October 1990), respectively (Figure 56).

Survey data and mass load estimates (Section 4.1.3) indicate that municipal discharges account for a considerable portion of the TP load in the western portion of the basin, and that non-point sources such as runoff from agricultural land are also important contributors. To determine the relative contribution from these sources accurately, much more detailed and intensive work is required than could be justified in a water quality overview. If such detailed study were to be undertaken it would be most relevant to quantify the proportion of biologically available phosphorus (BAP) in each source. The BAP, or that portion of the TP that is readily available for plant growth, can vary considerably depending on the source. Recently, Kallqvist and Berge (1990) showed that cereal crop cultivation runoff contained a much lower proportion of BAP than manure leakage, which in turn contained a smaller portion of BAP than sand-filtered sewage.

There are no CWQG or PPWBO for phosphorus in surface waters. AASWQIG specify that TP levels should not exceed 0.05 mg/L. This objective was not met by average TP concentrations for any of the sites monitored in 1989 and 1990, although it was met occasionally by individual measurements at the upper site (site 1) and at sites in the eastern portion of the basin (site 10-15).

4.3.4.3 Carbon

Total organic carbon includes both dissolved and particulate carbon. Carbon is the most abundant element found in all organisms and carbon compounds are the prime sources of energy and organic nutrient for heterotrophic organisms. The major source of production is through plant photosynthesis, but anthropogenic sources such as runoff from agricultural lands and from municipal and industrial wastewater discharges may increase organic carbon levels even further (CCREM 1987).

Total organic carbon (TOC) and particulate organic carbon (POC), which are flow dependent variables at Unwin (Table 9), exhibited a seasonal pattern marked by high median values in April, and followed a gradual decline to low winter values (Figure 59). Dissolved organic carbon (DOC), which is independent of flow, had an indistinct seasonal pattern at Unwin.

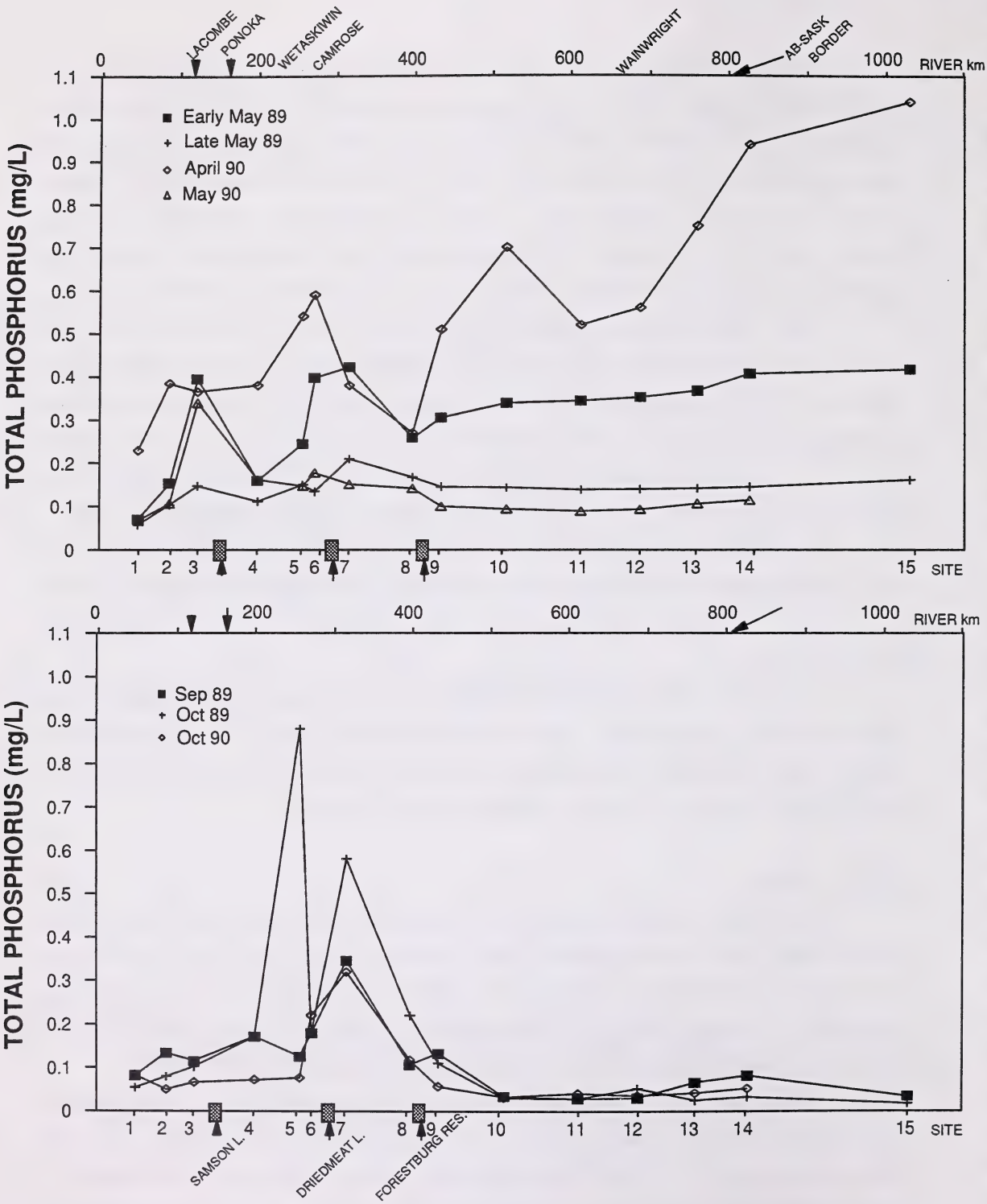


FIGURE 58. TOTAL PHOSPHORUS - longitudinal changes recorded during spring and fall surveys (1989-1990).

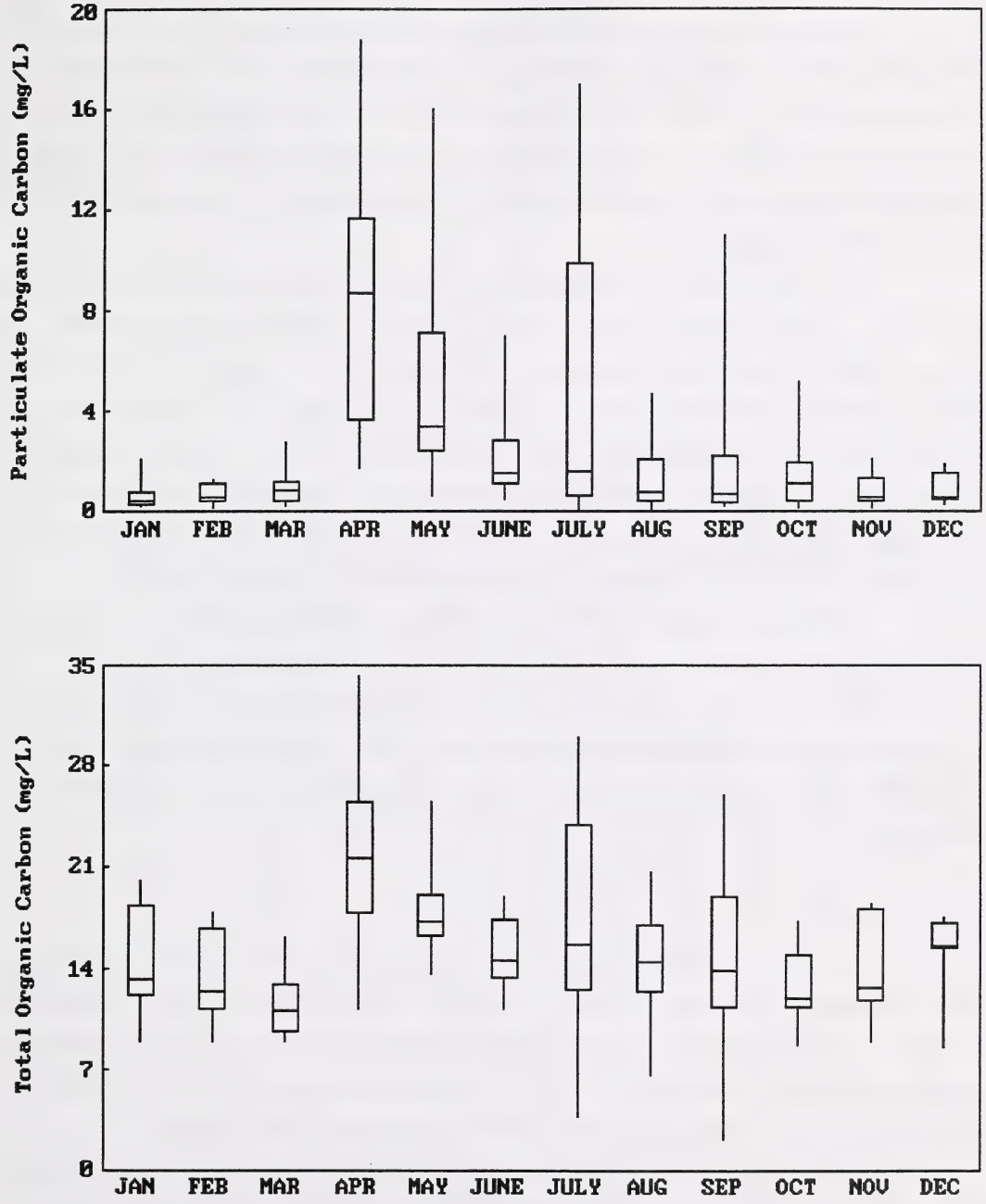


FIGURE 59. PARTICULATE AND TOTAL ORGANIC CARBON - SEASONAL CHANGES AT UNWIN (1977 - 1990).

There was a significant increase of 0.17 mg/L.yr DOC and of 0.04 mg/L.yr POC from 1977 to 1990 at Unwin (Table 10, Figure 60). The absence of a similar trend in TOC could be related to the shorter period of record (i.e., 1981-1990). The trend in DOC and POC may suggest that the Battle River has become more productive over the period of record. However, this interpretation is not backed up by similar trends in other measures of productivity, such as inorganic nutrients or Chlorophyll *a (*Chl *a)* and the reason for the increase is obscure.

In the 1989-1990 surveys, most of the TOC in the Battle River occurred in dissolved form. Average POC and DOC increased from a minimum at site 1 (1.2 mg/L POC, 10.6 mg/L DOC) to a maximum at site 7, downstream of Driedmeat Lake (8.4 mg/L POC, 18.7 mg/L DOC), but stabilized further downstream at about 4 mg/L for POC and 14 mg/L for DOC (Figure 61, 62). The largest increases in average DOC and POC concentrations occurred downstream of Samson Lake and downstream of Driedmeat Lake and they reflect the importance of these lakes as contributors of organic matter to the Battle River. The discharge of municipal effluents did not coincide with in-stream increases in concentrations of DOC or POC comparable to those recorded for several other constituents.

POC levels in tributaries were generally comparable to those at mainstem sites, but tributaries in the eastern portion of the basin tended to have higher DOC levels than mainstem sites.

There are no surface water quality objectives or guidelines for carbon. Compared to other rivers in Alberta such as the North Saskatchewan (Shaw et al. 1992) or the Peace River (Shaw et al. 1989), levels of DOC and POC in the Battle River tend to be somewhat higher, particularly in the western portion of the basin.

4.3.4.4 Silica

Silica (SiO_2 or H_4SiO_4) refers to silicon in natural waters. Silica is present in most rocks, especially feldspars, micas and clay minerals (CCREM 1987). Anthropogenic sources of silica include the fluoridation of drinking water and the use of aerosols (McNeely et al. 1979). Silica is considered an essential micro-nutrient for diatoms (CCREM 1987). Diatoms utilize large amounts of silica to synthesize their frustules and silica concentrations can be significantly influenced by diatom cycling.

At Unwin, silica was independent of river flows (Table 9), but showed pronounced seasonal changes (Figure 63). Concentrations were highest in winter and declined considerably in early spring. A second drop in concentrations in September was followed by a gradual increase over the rest of the year. This seasonal pattern may reflect the occurrence of spring and fall blooms of diatoms.

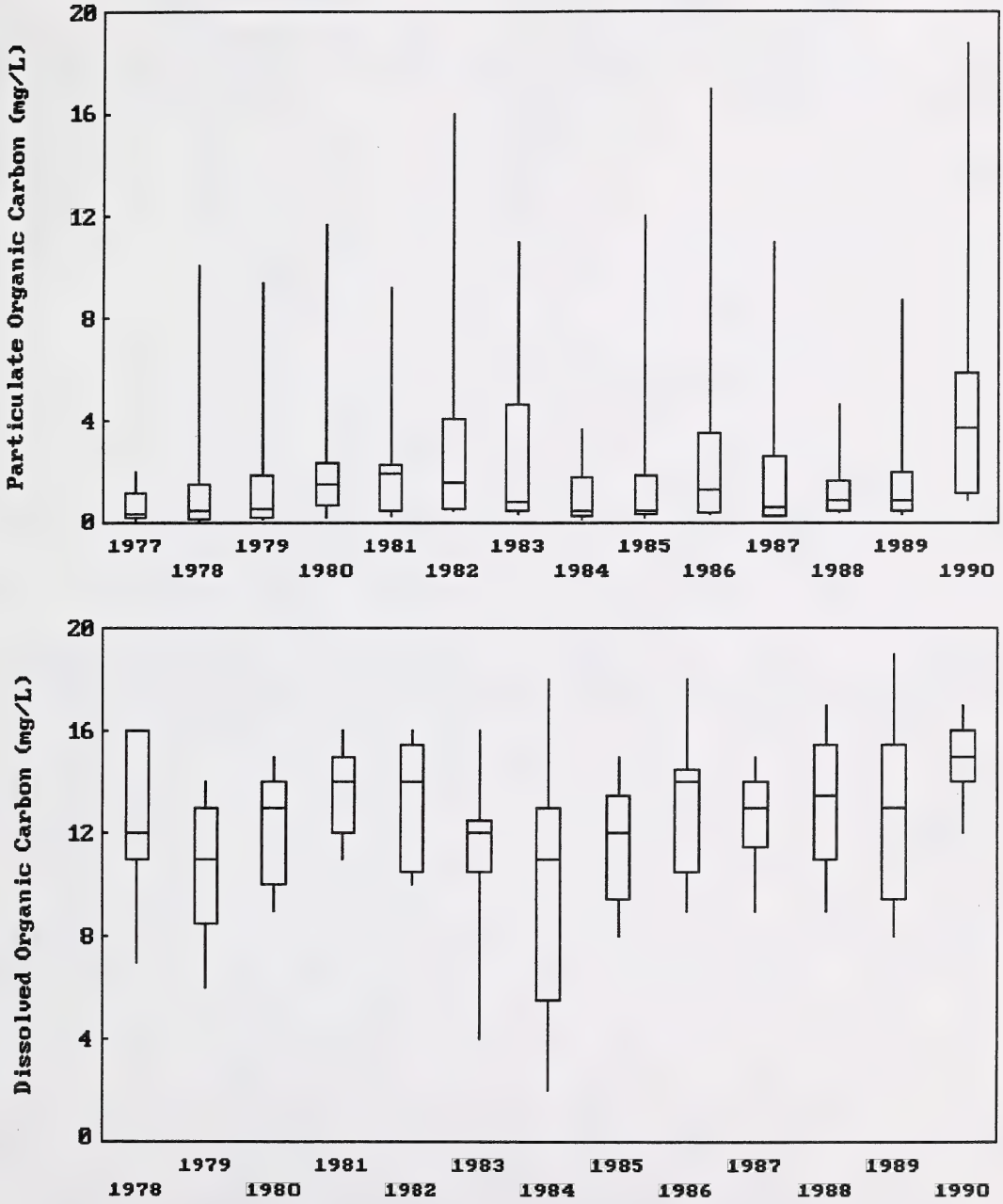


FIGURE 60. PARTICULATE AND DISSOLVED ORGANIC CARBON - YEAR-TO-YEAR CHANGES AT UNWIN (1977 - 1990).

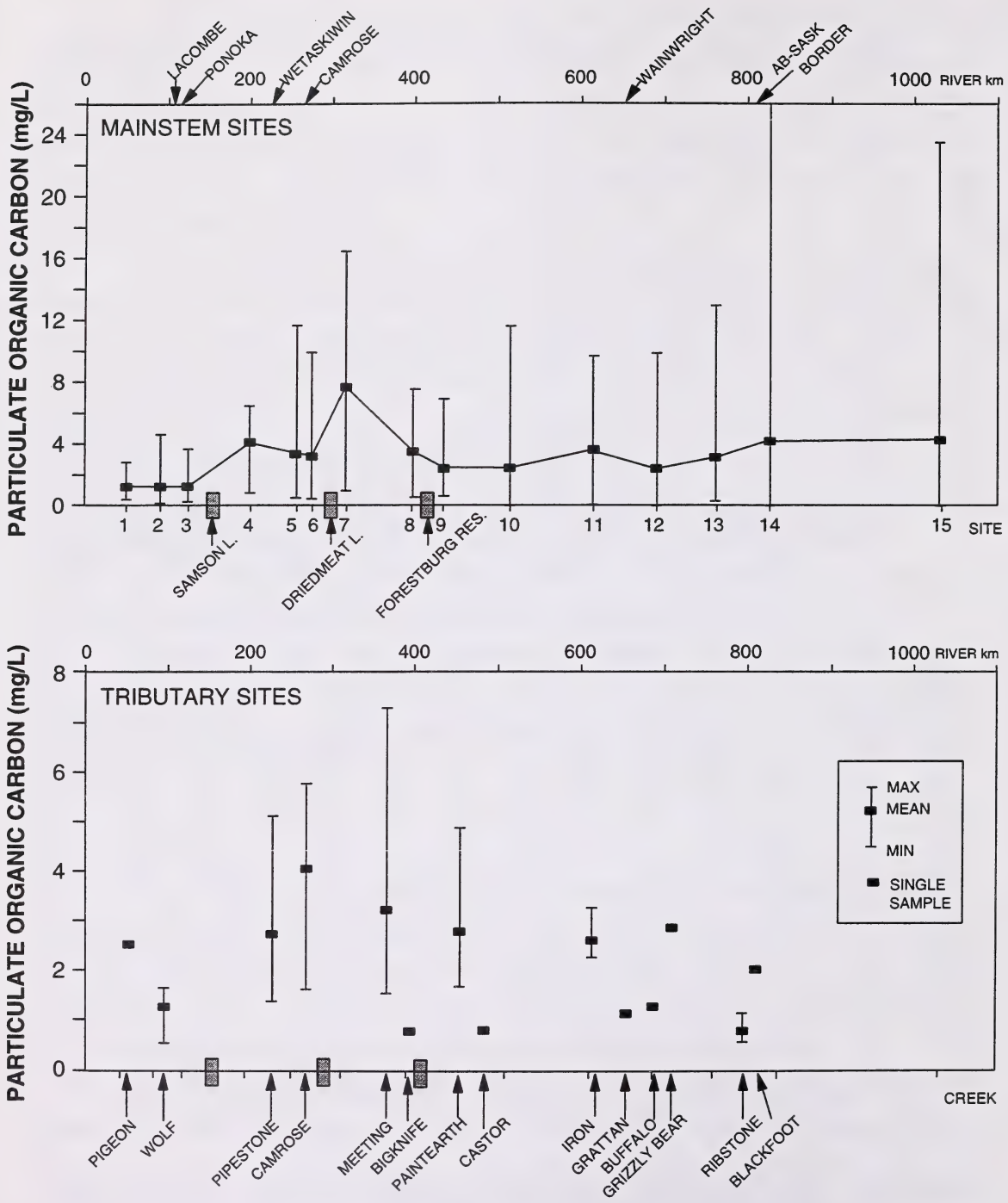


FIGURE 61. PARTICULATE ORGANIC CARBON in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

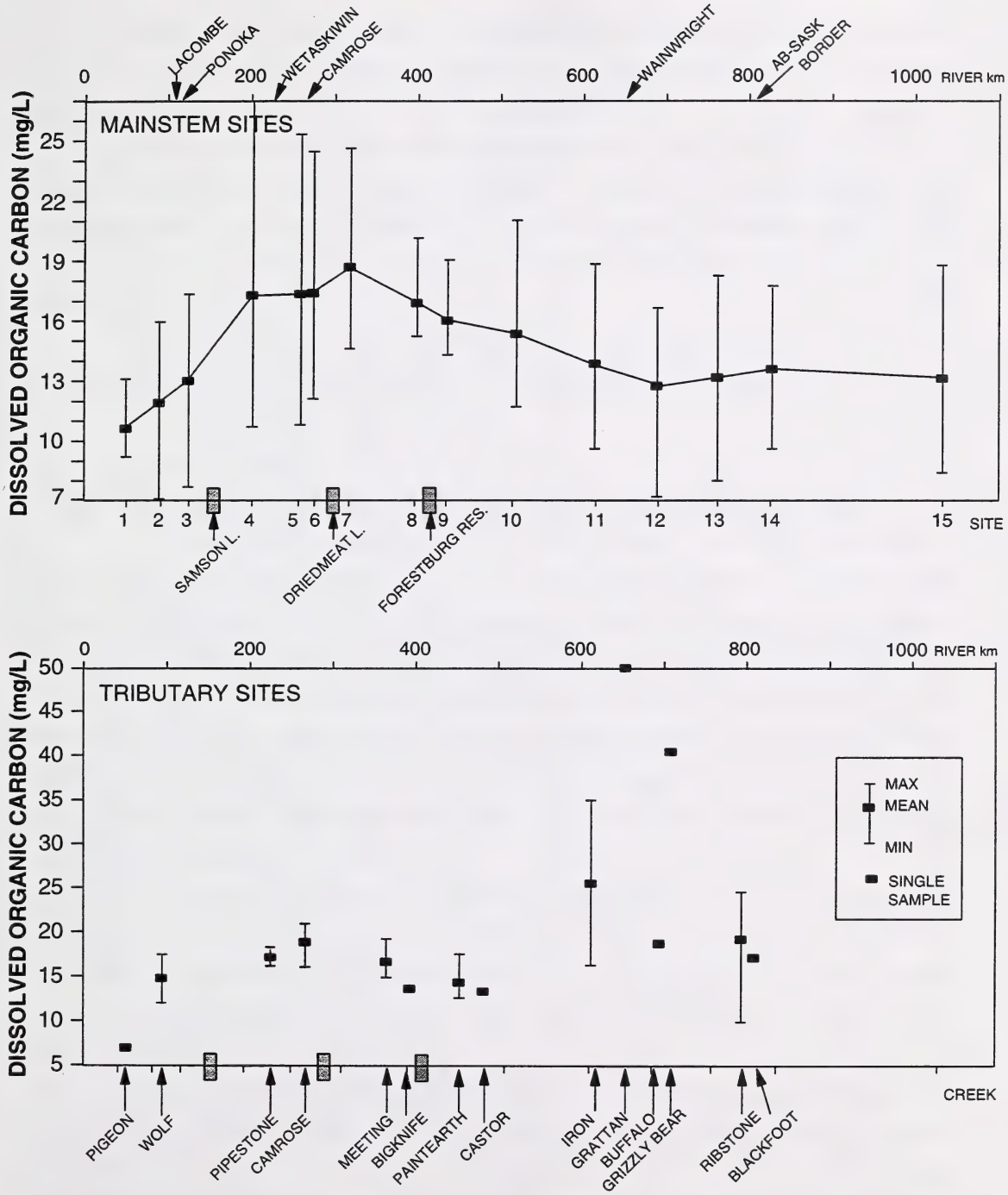


FIGURE 62. DISSOLVED ORGANIC CARBON in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

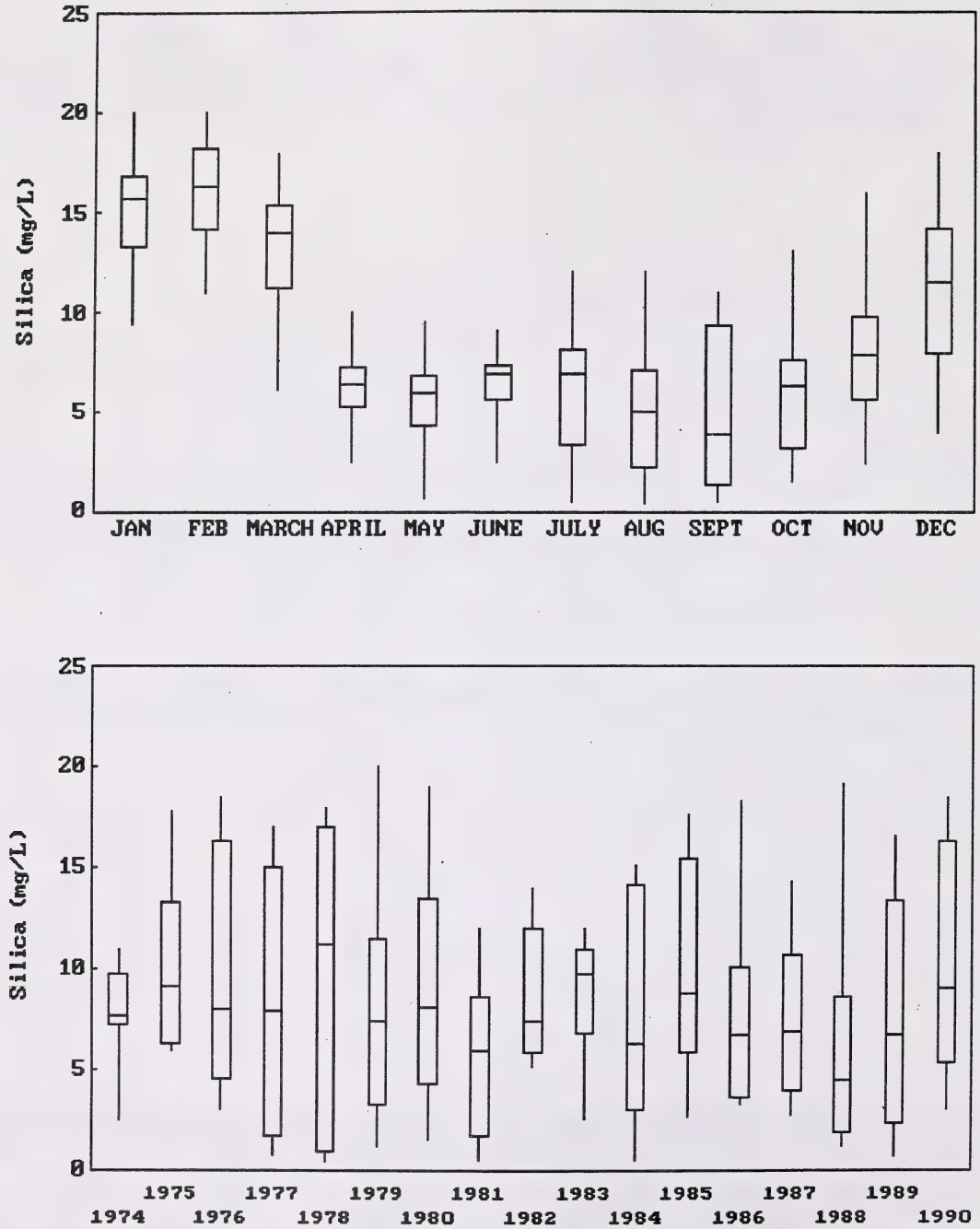


FIGURE 63. SILICA. SEASONAL AND YEAR-TO-YEAR VARIABILITY AT UNWIN.

Long-term trend analysis revealed a significant decline (0.16 mg/L.yr) in silica at Unwin over the period of record. Declines of a similar magnitude have also been recorded in other rivers of Alberta (Shaw et al. 1989, Shaw et al. 1992) and have no obvious explanation.

In 1989-1990, average silica concentrations ranged from 2.5 mg/L at site 1 (Highway 611) to 7.0 mg/L at site 8 (Bigknife Provincial Park). Overall there was a gradual increase in concentration in a downstream direction (Figure 64). Concentrations were quite variable and seasonal patterns were not well defined in survey data, although levels were usually highest in winter and lowest in fall surveys (Appendix 1).

There are no CWQG, PPWBO or AASWQIG for silica. Concentrations encountered in the Battle River are well within the range for surface waters in western Canada (CCREM 1987).

4.3.5 Organic Constituents

4.3.5.1 Phenolic Compounds

The term "phenolic compounds" refers to a family of organic compounds which possess a benzene ring to which one or more hydroxyl groups are attached. Phenol itself consists of one benzene ring with one hydroxyl group. The benzene ring can undergo a variety of substitutions. Some phenolic compounds are resistant to biological degradation and can thus be transported long distances in the water (McNeely et al. 1979). Phenolic compounds may occur naturally in aquatic environments because many phenols are decomposition products of aquatic plants and decaying vegetation; industrial and municipal discharges can be major anthropogenic point sources of phenols in aquatic systems. Phenols can become toxic to aquatic organisms at high concentrations, but even low concentrations can taint fish and impart taste and odour to drinking water (CCREM 1987).

At the long-term network site on the Battle River concentrations of phenolic compounds were independent of river flow (Table 9) and did not follow a distinct seasonal pattern. A decline of 0.00017 mg/L.yr was detected over the period of record (Table 10). However, this trend appears to be an artifact due to a change in analytical methods during the summer of 1975. No trend was detected in the data from 1976 to 1990.

During the 1989-1990 surveys average concentrations of phenolic compounds ranged from about 0.007 to 0.013 mg/L. Highest average concentrations occurred in the river stretch between Samson Lake and the Forestburg Reservoir (Figure 65). Variability among seasonal surveys was also much larger in that portion of the river than at sites downstream of the reservoir.

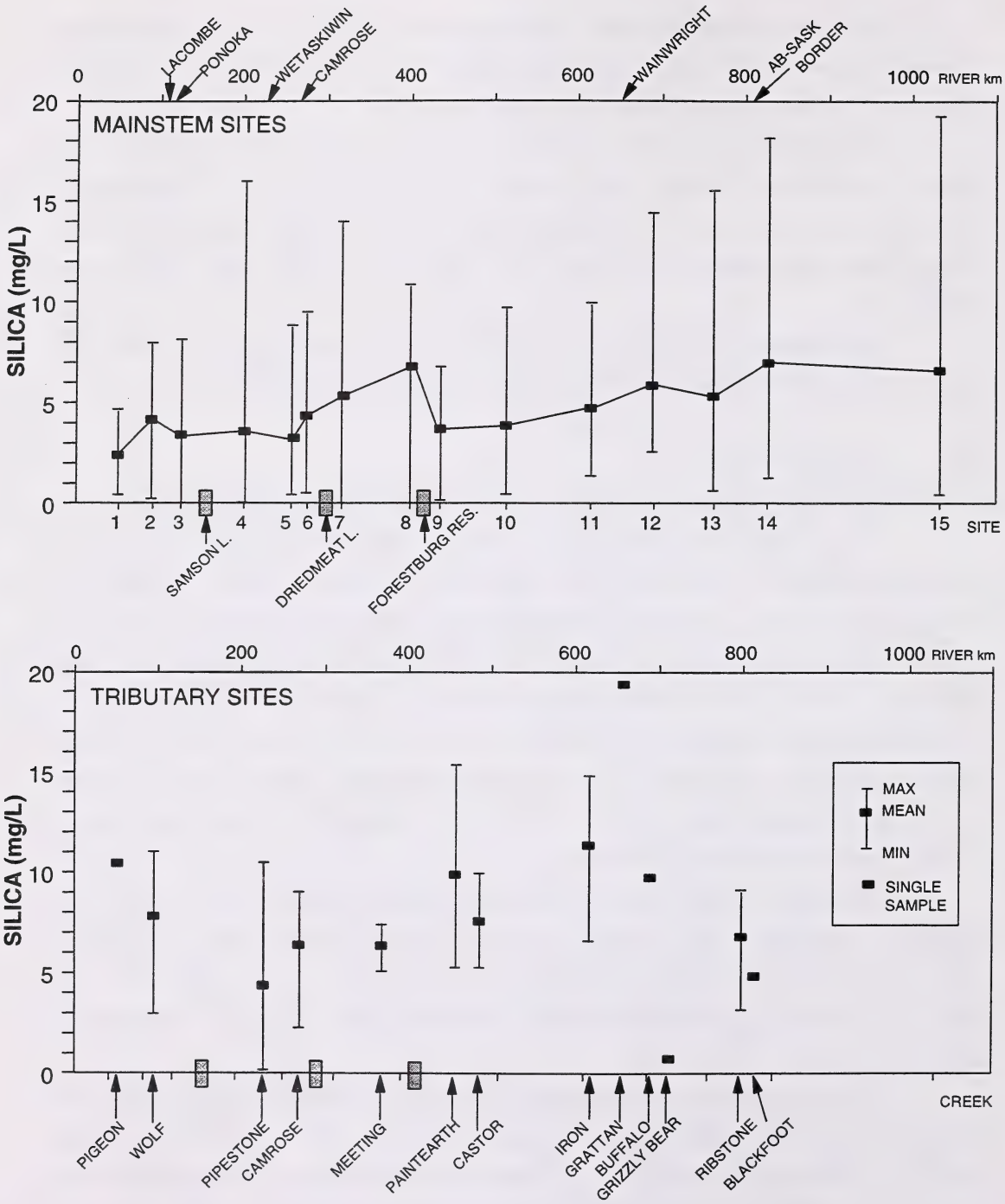


FIGURE 64. SILICA in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

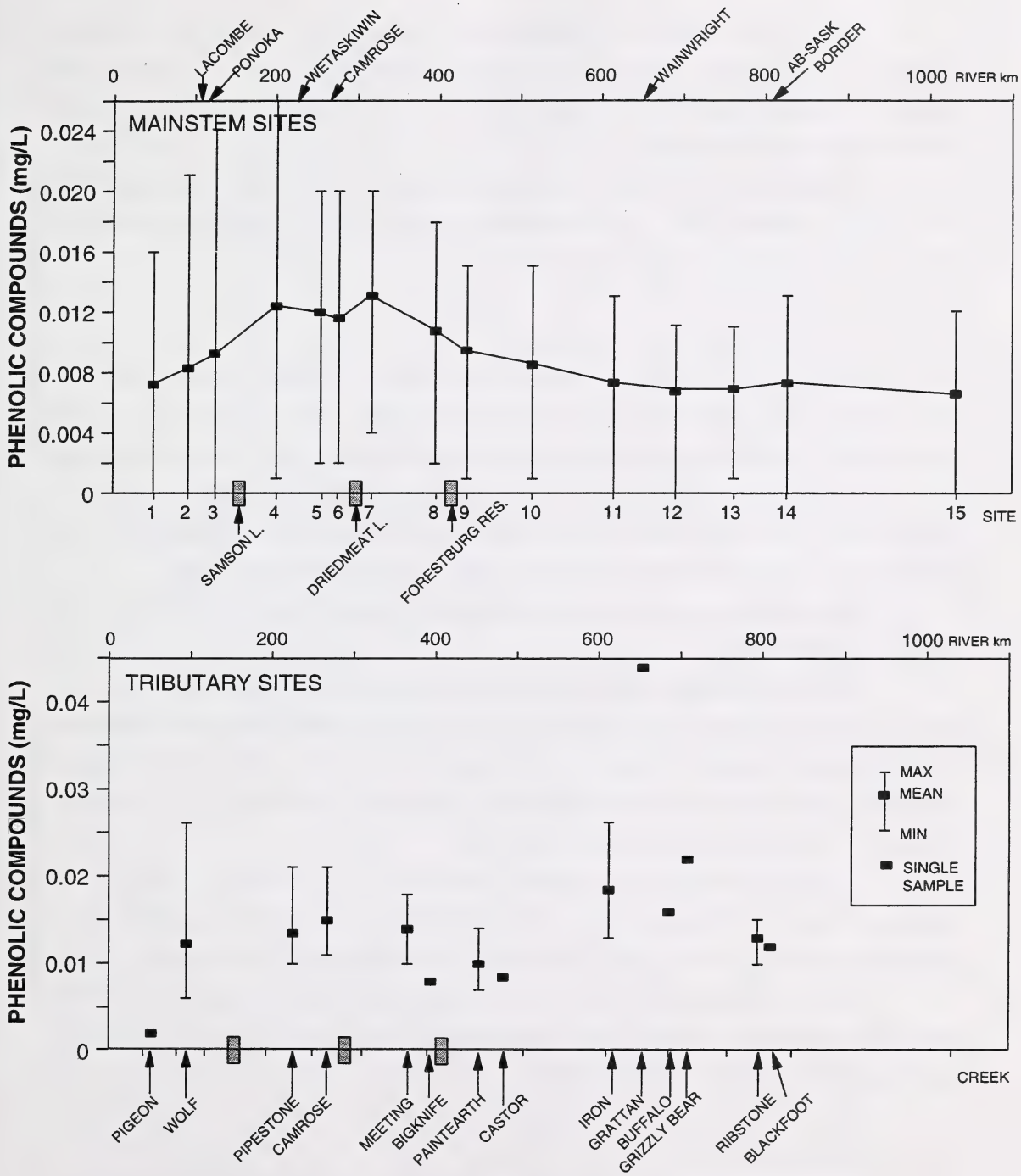


FIGURE 65. PHENOLIC COMPOUNDS in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

There was no synchronism between municipal discharges and concentration increases at mainstem sites and tributary concentrations were generally comparable to those at mainstem sites (Figure 65). Because of these two facts it is probable that phenolic compounds in the Battle River are primarily of natural and diffuse origin.

AASWQIG and CWQG specify that phenolic compounds should not exceed concentrations of 0.005 and 0.001 mg/L, respectively. These concentrations were exceeded by average concentrations at all mainstem sites and by concentrations in nearly all single samples.

4.3.5.2 Tannin and Lignin

Lignin is an amorphous, polymeric substance related to cellulose. Together, lignin and cellulose form the woody cell walls of plants and the cementing material between cells. Tannin refers to any of the various soluble, astringent, complex phenolic substances of plant origin. Tannin and lignin are both complex organic compounds which contain aromatic hydroxyl groups and which are resistant to microbial decay. As natural products of vegetation decay, tannin and lignin are ubiquitous in the environment and they are a common cause of colour in surface waters (McNeely et al. 1979).

Tannin and lignin were not routinely monitored at Unwin and there are no data to document seasonal or long-term trends.

During the 1989-1990 surveys, average concentrations increased gradually in a downstream direction from site 1 (Highway 611) to site 6 (downstream of Camrose Creek), then declined gradually to site 15 (Figure 66). Seasonal patterns were not sharply defined in survey data, although highest concentrations generally occurred at spring runoff time. As for phenolic compounds (4.3.5.1), variability in the data set was largest in the western portion of the basin.

Tributary concentrations were slightly higher than at mainstem sites but there was no synchronism between the timing of municipal wastewater discharges and changes in concentrations at mainstem sites. Therefore, tannin and lignin in the Battle River were primarily of natural origin.

There are no surface water quality objectives or guidelines for tannin and lignin concentrations. Concentrations measured in the Battle River and its tributaries were within the range of 0.1-2 mg/L for western Canadian surface waters (CCREM 1987).

4.3.5.3 Oil and Grease

The term "oil and grease" refers to a group of substances which are soluble in specific organic solvents rather than to definite chemical substances (CCREM 1987).

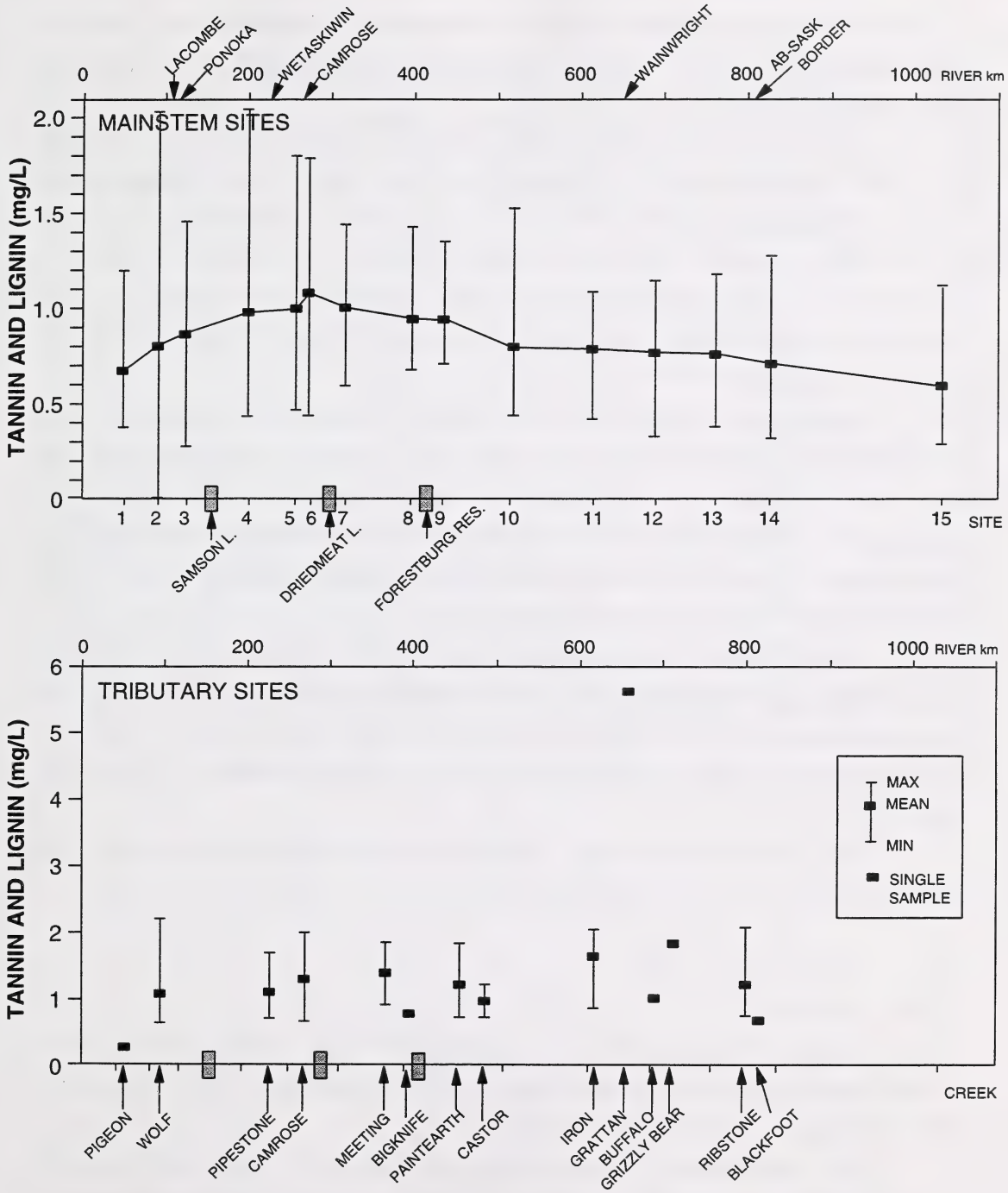


FIGURE 66. TANNIN AND LIGNIN in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

The long-term monitoring of oil and grease at Unwin was discontinued in 1981. Most of the records indicate that concentrations were at or below the detection limits, although there were individual records as high as 7 mg/L.

Oil and grease samples of 1989-1990 surveys were analyzed by two different methods (NAQUADAT code 06524 and 06521, Environment Canada 1988) which were used interchangeably from one survey to the next. One method (06524) uses freon extraction followed by infrared spectrophotometry and has a detection limit of 0.1 mg/L. In the other method (06521) oil and grease are extracted in petroleum ether and weighed; the detection limit is 1 mg/L. The use of these two methods generated a heterogeneous data base of limited value, because most records are near the detection limit of the least sensitive method (Appendix 1).

Measurable concentrations at site 1 to 7 did not exceed 1 mg/L. However, in the vicinity of the Forestburg Reservoir, concentrations as high as 3 mg/L were recorded and concentrations greater than 1 mg/L were recorded on one or more occasions at most sites downstream of the reservoir. The concentrations lie within the range of <1-4 mg/L given by CCREM (1987) for western surface waters. No oil film or odour was perceived at the time of sampling, the only specifications for oil and grease given by AASWQIG or by CWQG for recreation water quality.

Alberta Power Ltd. is the only licensed point source of oil and grease in the basin. Company data submitted to the Environmental Sciences Division (Alberta Environmental Protection) as part of license requirements show that all samples collected from the ash lagoon effluent contained oil and grease and that discharges averaged 12.14 kg/d (47 samples) and 5.69 kg/d (48 samples) in 1989 and 1990, respectively.

Only three tributaries, Pipestone, Iron, and Buffalo Creek had measurable levels of oil and grease in 1990 surveys. The concentrations were comparable to those at mainstem sites (Appendix 1).

4.3.5.4 Trace Organic Compounds

4.3.5.4.1 Pesticides

Among the 44 pesticides which have been monitored at Unwin since the mid-1970's, only 14 have been detected on one or more occasions (Table 17), and among these gamma-BHC (Lindane), alpha-BHC and 2,4-D have been detected most frequently.

The organochlorine pesticides alpha- and gamma-BHC are stereoisomers of hexachlorocyclohexane. Gamma-BHC or Lindane is registered in Canada for controlling ticks and flies on livestock, seed treatment for wireworm control, and the control of insect infestations of stored logs. Alpha-

Table 17. List of pesticides detected in the Battle river at Unwin, Saskatchewan, from 1974-1990.

COMPOUND	HIGHEST CONCENTRATION (µg/L)	# OF SAMPLES / # OF DETECTIONS
P,P-DDD	0.003	162/1
Gamma-BHC	0.030	172/75
Alpha-BHC	0.02	159/140
Trifluralin	1.14	71/2
Atrazine	0.10	55/1
2,4-D	0.755	174/66
2,4,5-T	L0.05	173/3
2,4-DP	0.06	155/4
MCPA	0.3	155/4
MCPB	0.11	62/2
Dicamba	0.05	62/1
Silvex	0.055	138/1
2,4-DB	0.090	154/1
Picloram	0.110	59/5

BHC has no active insecticidal activity, it is a component of BHC (Technical grade) which is a mixture of isomers and the raw material from which the purified gamma-isomer is extracted (CCREM 1987). 2,4-D is a phenoxy acid herbicide which is used for broad leaf weed control; it has agricultural, industrial and domestic applications.

There were too many records below the detection limit to assess trends in the long-term data of most pesticides, except alpha- and gamma-BHC. Both pesticides were independent of flow at Unwin (Table 9). A trend towards a slight decline (0.00029 µg/L.yr) was detected for alpha-BHC (Table 10, Figure 67), but concentrations of gamma-BHC have not changed over the period of record. The trend for alpha-BHC corresponds to the findings of Shaw et al. (1989, 1992) in the Peace and North Saskatchewan rivers, but an increase in gamma-BHC levels was also detected in the North Saskatchewan River.

In 1989-1990, pesticides were monitored seasonally at six mainstem sites using routine sampling techniques and routine analytical techniques for long-term river network samples. None of these samples contained detectable levels of pesticides.

A pilot study (Anderson et al. 1992) run concurrently with the routine water quality surveys showed that pesticides were present in the river water, but that more sensitive analytical methods (National Water Quality Laboratory a, b, c, undated) or extracts from larger samples were required in order to detect them. In that pilot study, 12 pesticides were detected in the river's water and among these 2,4-D, MCPA, gamma-BHC, 2,4-DP, dicamba, bromoxynil and triallate were detected most frequently. There was a close relationship between pesticide usage in Alberta and pesticide detections in the river water. Seasonal and longitudinal changes in detection frequency and detected concentrations were related to application patterns. Pesticides were also detected in media other than river water. Triallate was detected occasionally in the river's sediments and some biological samples (i.e., aquatic invertebrates, macrophytes, fish) contained metolachlor, triallate, pp-DDE, dieldrin, HCB and PCB.

The Battle River basin is an intensively farmed area in Alberta and it was selected for the pilot study because of the likelihood of detecting a variety of pesticides. Herbicides and sterilants are also used on industrial sites (such as oil and gas wells), along right-aways, roads and on lawns and gardens. However, the number of pesticide detections, the variety of detected compounds and the reported concentrations are more a reflection of the intensive nature of the project and the sophisticated technology employed than of a particularly high level of contamination. Indeed, most of the pesticides detected in the water occurred at concentrations which were three or more orders of magnitude below the most restrictive objectives or guidelines (Table 18). The sum of BHC isomers (i.e., alpha plus gamma) was the only group

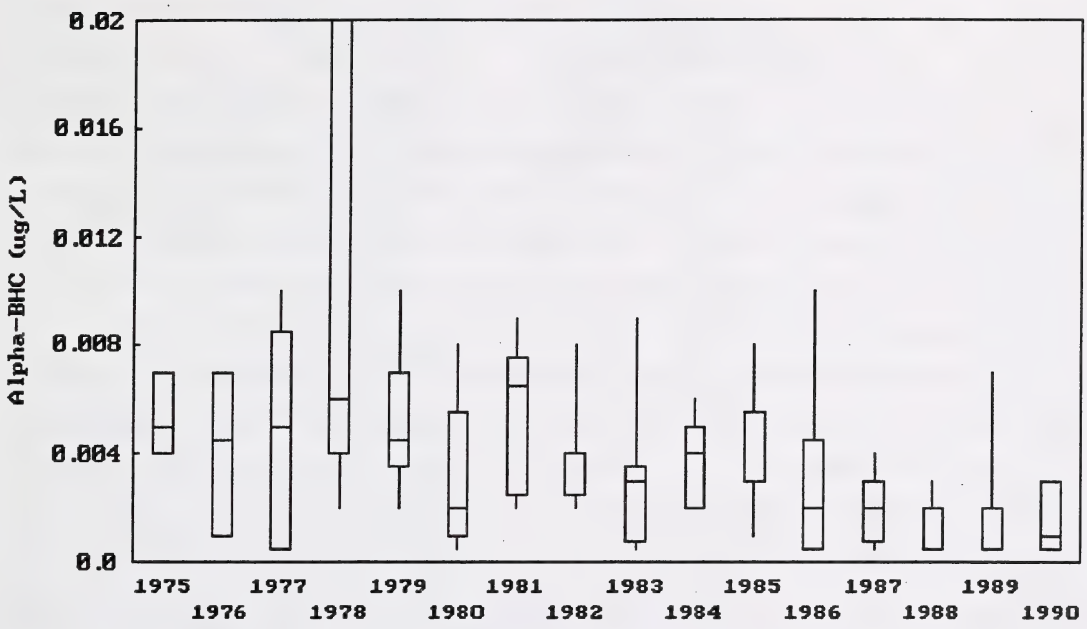


FIGURE 67. ALPHA-BHC - YEAR-TO-YEAR VARIABILITY AT UNWIN.

Table 18. Comparison of pesticide levels in the Battle River with water quality objectives[1].

	MAXIMUM CONCENTRATION[2] ng/L	WATER QUALITY OBJECTIVE[3] ng/L	RATIONALE[4]
2,4-D	90.0	4,000 (a)	PAL
gamma-BHC	4.0	10 (a)	PAL
MCPA	5.1	440 (b)	DW
alpha-BHC	2.0	10 (a)	PAL
2,4-DP	60.0	NA	
Dicamba	1.7	120,000 (c)	DW
Bromoxynil	6.7	5,000 (c)	DW
Triallate	2.4	230,000 (c)	DW
Atrazine	13.0	2,000 (d)	PAL
2,4,5-T	4.1	280,000 (c)	DW
2,3,6-TBA	2.2	NA	
Trifluralin	0.42	35,000 (b)	DW

[1] Source: Anderson et al. 1992

[2] Maximum concentrations found in large volume extractions

[3] (a) CCREM 1987; (b) NYSDEC 1986; (c) HWC 1987; (d) Trotter et al. 1990
NA = no objective available

[4] PAL = protection of freshwater aquatic life
DW = maximum concentration in drinking water

of compounds which approached CWQG (10 ng/L) on two occasions at Unwin with concentrations of 6 mg/L.

4.3.5.4.2 Non-Pesticides

Hydrocarbons, aromatic hydrocarbons and hexachlorobenzene are the only three non-pesticide trace organic compounds which have been monitored at the long-term site on the Battle River. Only one detection of hexachlorobenzene (0.001 µg/L, detection limit: <0.001 µg/L) has been reported in 145 samples and the two other components were not detected in nearly 60 samples.

Hydrocarbons and trace organic (semi-volatile) compounds (Table 2) were monitored on four occasions at six mainstem sites during the 1989-1990 surveys. No hydrocarbons were detected, but phthalate compounds and hexadecanoic acid were detected in many samples (Table 19). Phthalate esters represent a large group of chemicals widely used as plasticizers in polyvinyl chloride resins, adhesives and cellulose film coating. Other applications are found in cosmetics, rubbing alcohol, insect repellant, insecticides, tablet coating and solid rocket propellants (CCREM 1987). These compounds are often detected in field blanks (Noton and Shaw 1989, EQMB unpublished data). It is probable that in the Battle River, as in the North Saskatchewan River (Shaw et al. 1992), most of the detections of phthalates and hexadecanoic acid were the result of sample contamination in the field or in the laboratory. However, contamination may not explain the detection of a large amount of Bis(2-ethylhexyl) phthalate at the mouth (site 15) in May 1989 (Table 19). There is no known point source of this or other phthalates in the vicinity of that site.

4.3.6 Metals

4.3.6.1 Introduction

Metals are natural constituents of the earth's crust; some such as aluminum are abundant in all rock types and most geologic materials, whereas others, usually referred to as trace metals, are generally encountered at very small concentrations (Forstner and Wittmann 1981). Human activities affect geochemical cycling and result in increased environmental concentrations or availability of metals.

Metals are of concern because of their toxicity. Problems associated with metal toxicity can become amplified because living organisms possess the ability to concentrate metals in their tissues (bioconcentration) and because of the possibility of further concentration of some metals along the food chain (biomagnification).

Table 19. Trace organic compounds detected at mainstem sites in the Battle River (µg/L).

	HEXADECA NOIC ACID	DIBUTYL PHTHALATE	BUTYLBENZLE PHTHALATE	DI-N-OCTYL PHTHALATE	BIS (2-ETHYLHEXYL) PHTHALATE
Highway 611					
May 1989	-	2	-	-	-
Jan. 1990	trace	-	4	1	5
Feb. 1990	trace	3	3	7	2
Highway 53					
May 1989	-	-	-	-	4
Jan. 1990	-	trace	trace	trace	trace
Feb. 1990	-	3	trace	trace	trace
d/s Camrose					
May 1989	-	trace	-	-	-
Jan. 1990	-	trace	trace	1	1
Feb. 1990	3	2	4	2	4
Highway 872					
May 1989	-	trace	-	-	-
Jan. 1990	-	trace	trace	trace	1
Feb. 1990	3	3	2	2	3
Unwin					
July 1989	-	trace	-	-	trace
Jan. 1990	4	trace	trace	-	2
Feb. 1990	4	-	2	-	2
Mouth					
May 1989	-	3	-	2	3067
July 1989	-	trace	-	-	-
Jan. 1990	-	trace	trace	-	trace
Feb. 1990	4	4	6	1	4

Trace: concentration < detection limit

Environmental concentrations of metals are influenced by human activities, but also by complex abiotic and biotic processes. According to Campbell et al. (1988) adsorption/desorption onto solid phases and oxidation-reduction reactions have a considerable influence upon the distribution of chromium, copper, mercury, arsenic, selenium, iron, and manganese, whereas precipitation-dissolution processes are also important for iron and manganese. The authors emphasize the importance of microbial transformations such as methylation and demethylation which may alter the metal species present and thus affect the geochemical mobility, bioavailability, and inherent toxicity of metals.

Metals do not degrade. In rivers, they are transported by water or stored in sediments or biota and can become remobilized and available under appropriate conditions. Therefore, with few exceptions, surface water quality guidelines apply to total metal levels rather than to specific metal species. Recognizing the potential importance of sediments and biota as temporary sinks for metals in the Battle River, Anderson et al. (1992) measured concentrations of selected trace metals in Battle River sediments and in various types of invertebrates, macrophytes and fish. Some of the findings of that study, which was concurrent with the 1989-1990 general water quality surveys, are summarized here; the reader is referred to Anderson et al. (1992) for detailed information and discussion.

Total metal concentrations are usually highly dependent upon river discharge and transport of suspended materials (Forstner and Wittmann 1981, Feltz 1980). Such dependence was demonstrated for most total metals in the Battle River, but dissolved metals were usually independent of discharge or NFR levels (Table 9, this report; Anderson et al. 1992). Much of the longitudinal, seasonal, and year-to-year variability in the total and extractable metal data for the Battle River is related directly to variability in flow and NFR concentrations.

4.3.6.2 Aluminum

Aluminum is the third most abundant element in the earth's crust (Forstner and Wittmann 1981). Alumino-silicate minerals are abundant in all rock types and most geologic materials. Acidification accelerates the release of aluminum from soils and sediments through natural weathering. In surface waters, aluminum concentrations tend to increase with declining pH and aluminum is generally more toxic over the pH range of 4.4 to 5.4 (CCREM 1987).

Extractable aluminum concentrations have increased significantly (0.013 mg/L.yr) at Unwin between 1981 and 1990 (Table 10, Figure 68). There is no obvious reason that could account for this increase. Note that data collected prior to 1981 were not included in the analysis because of changes in

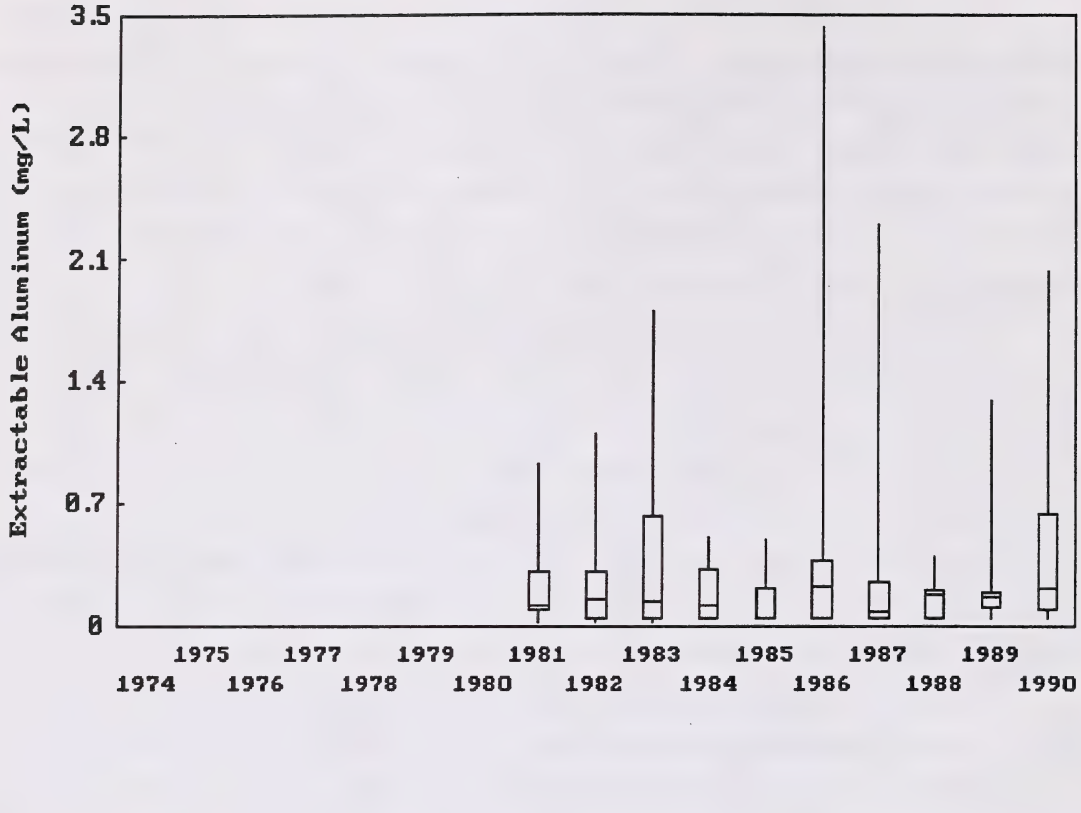


FIGURE 68. EXTRACTABLE ALUMINUM-YEAR-TO-YEAR CHANGES AT UNWIN.

analytical methods. For the entire period of record concentrations averaged 0.356 mg/L and ranged from 0.020 to 3.430 mg/L.

During the 1989-1990 surveys, concentrations of extractable aluminum ranged from less than the detection limit (<0.0002 mg/L) to 2.232 mg/L. Average concentrations increased gradually in a downstream direction and maxima were generally recorded at high flows in spring (Figure 69). Tributary concentrations were within the range of concentrations for mainstem sites and highest concentrations were also associated with highest discharge. Pipestone Creek contributed the largest load of aluminum to the Battle River (Table 11, Appendix 7).

There are no AASWQIG for aluminum. PPWBO specify an upper limit of 5 mg/L for livestock watering. This guideline was met by all long-term and 1989-1990 survey data. CWQG for the protection of aquatic life specify that at pH>6.5 and the range of calcium and dissolved organic carbon concentrations which prevail in the Battle River, total aluminum concentrations should not exceed 0.1 mg/L. This guideline was exceeded by most average concentrations at sites in the lower portion of the basin (site 11 to 15) and by about 25% of individual concentrations measured in 1989-1990 surveys. Most of these non-compliant records were associated with high river flows and high NFR concentrations. Three non-compliant records in Pipestone and Camrose Creek coincided with wastewater discharges from Wetaskiwin (April 1990), and Camrose (May and October 1990), respectively.

4.3.6.3 Arsenic

Arsenic minerals are widely distributed; the most common are those in which arsenic is combined with sulphur and iron or nickel. Arsenic is released into the environment by weathering of these minerals (CCREM 1987). Among the anthropogenic sources of arsenic cited by CCREM (1987) those which are potentially most relevant to the Battle River basin include the combustion of fossil fuels, especially coal and municipal discharges.

Dissolved arsenic has been monitored at Unwin since 1974, and no significant concentrations changes have occurred over that period (Table 10). Concentrations of dissolved arsenic averaged 0.0013 mg/L and ranged from 0.0003 mg/L to 0.0039 mg/L at Unwin over the period of record. Seasonal highs for dissolved arsenic occur during the summer months (June to September, Figure 70). This pattern which is nearly the mirror image of the seasonal pattern for dissolved iron (Figure 76), may indicate that co-precipitation or sorption of dissolved arsenic with hydrous iron oxides is important in the removal of dissolved arsenic from the water column as indicated by CCREM (1987). Such processes may also

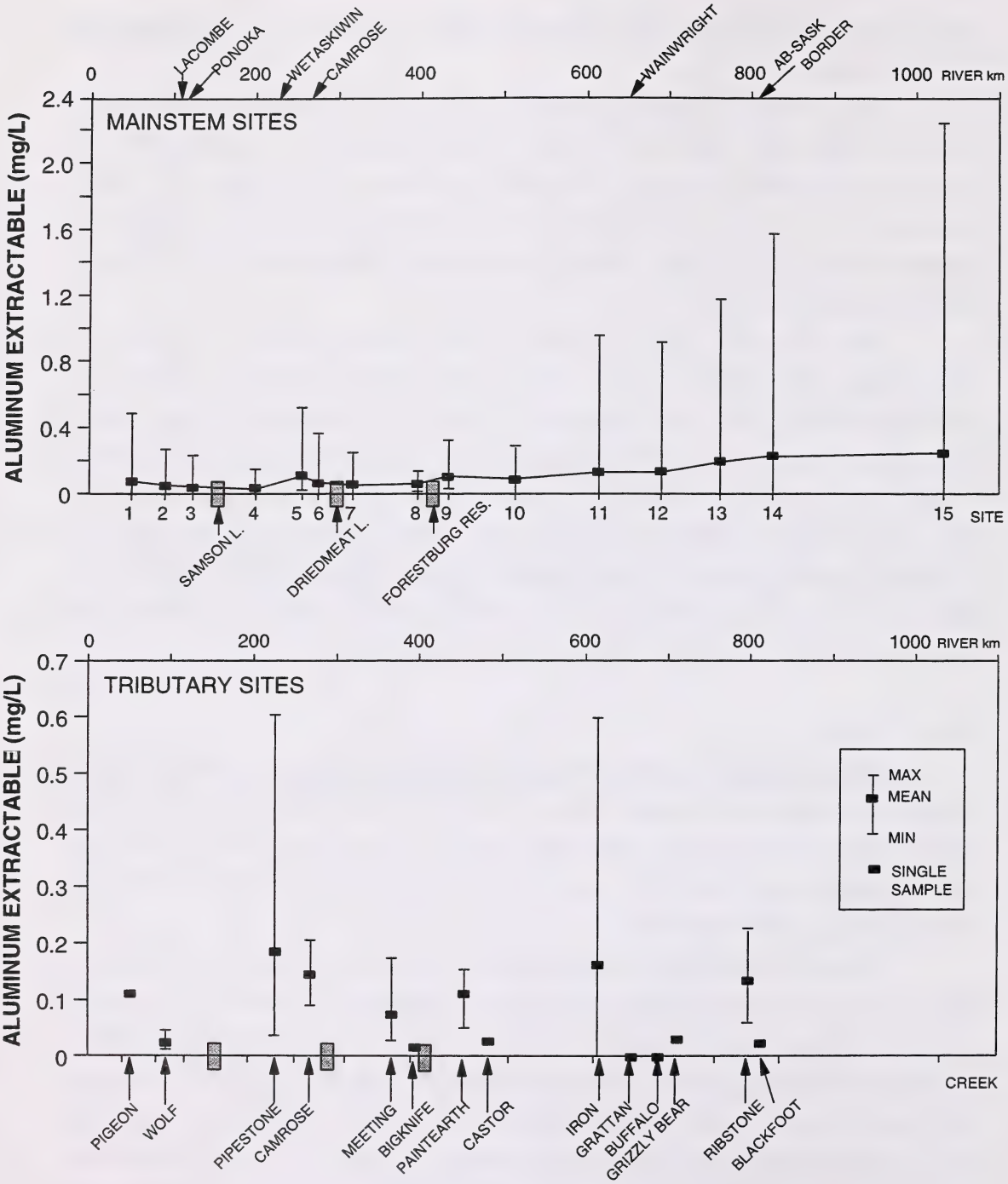


FIGURE 69. ALUMINUM EXTRACTABLE in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

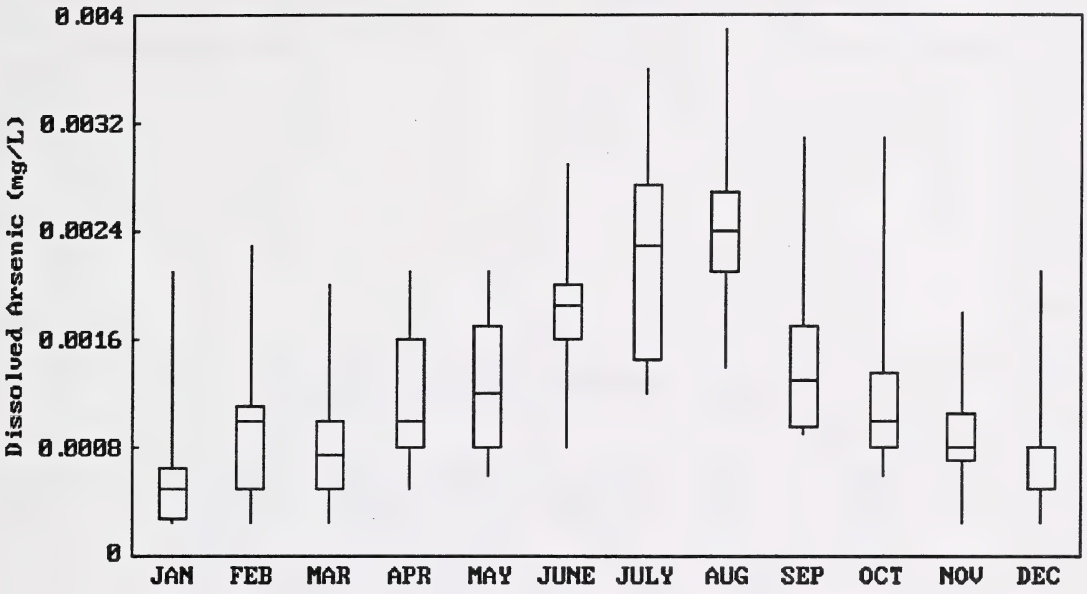


FIGURE 70. DISSOLVED ARSENIC SEASONAL CHANGES AT UNWIN (1974 - 1990).

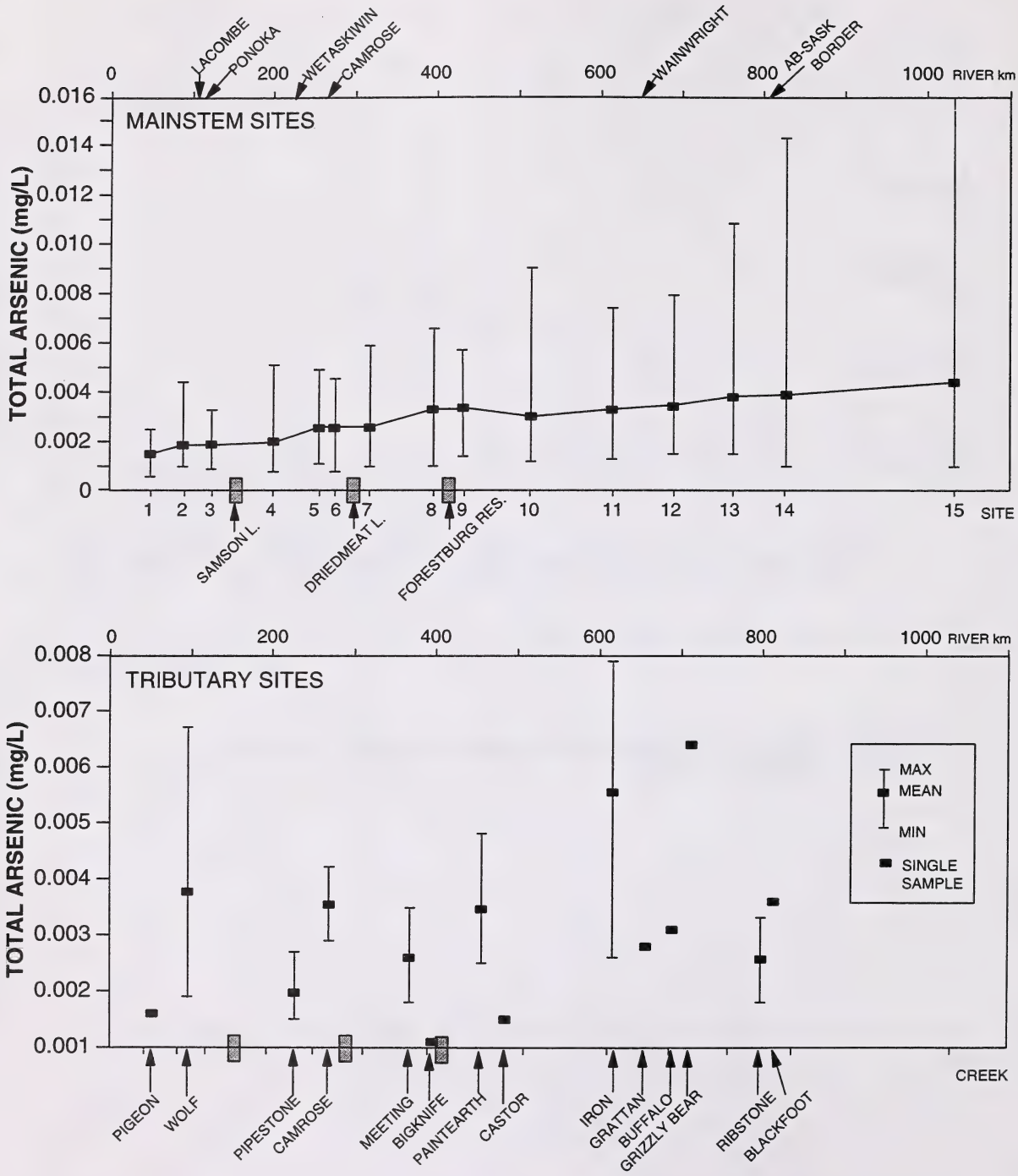


FIGURE 71. TOTAL ARSENIC in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

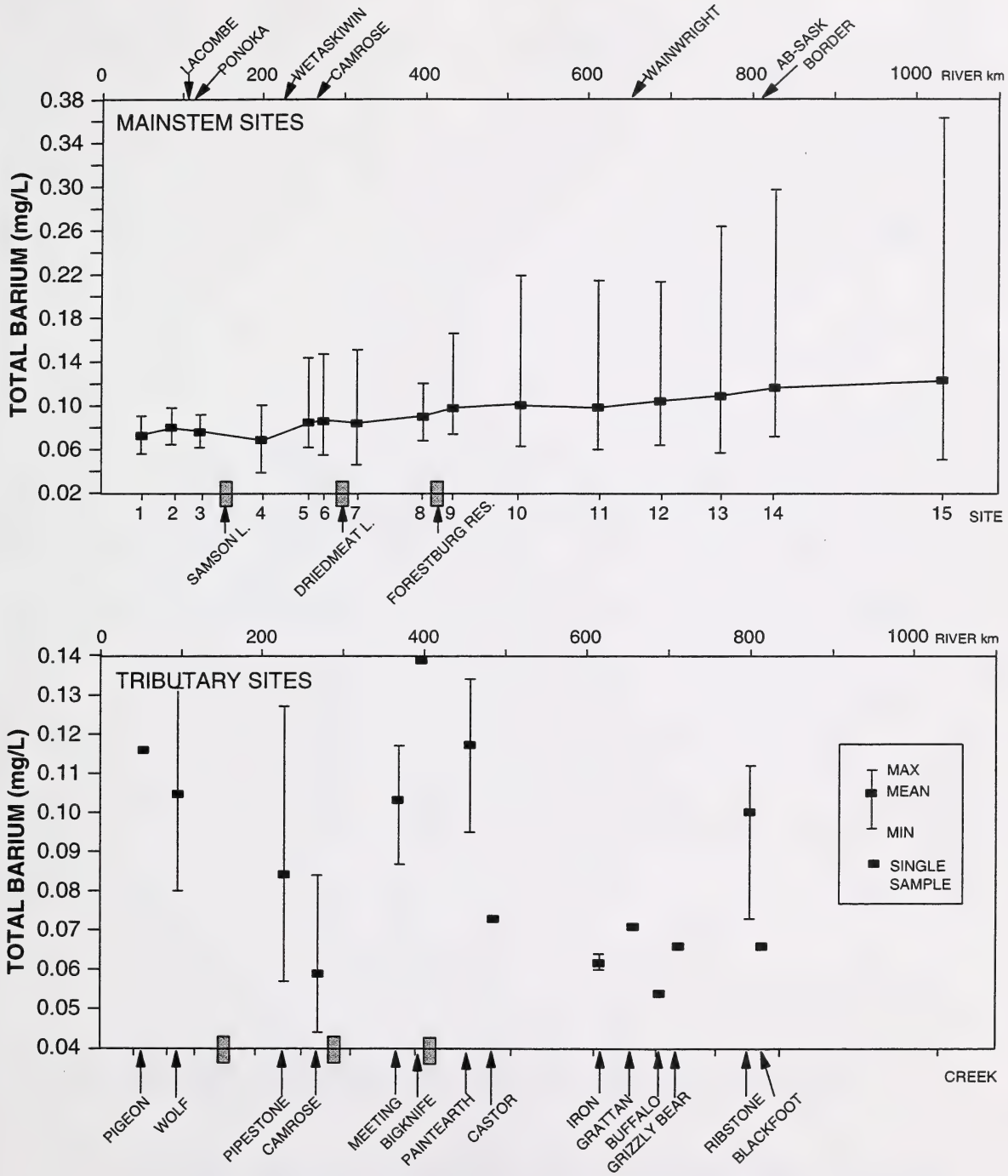


FIGURE 72. TOTAL BARIUM in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

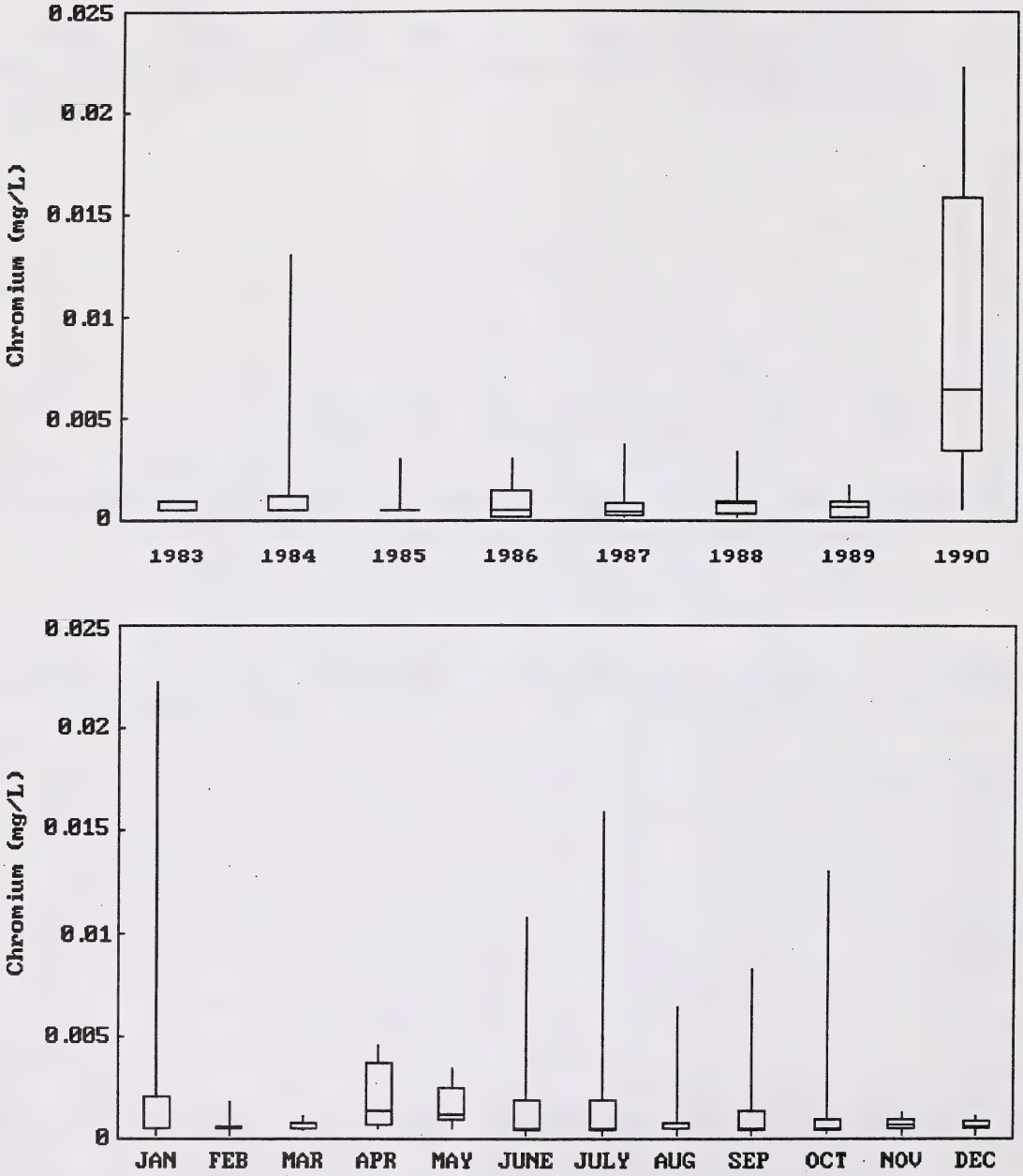


FIGURE 73. TOTAL CHROMIUM-YEAR-TO-YEAR AND SEASONAL CHANGES AT UNWIN.

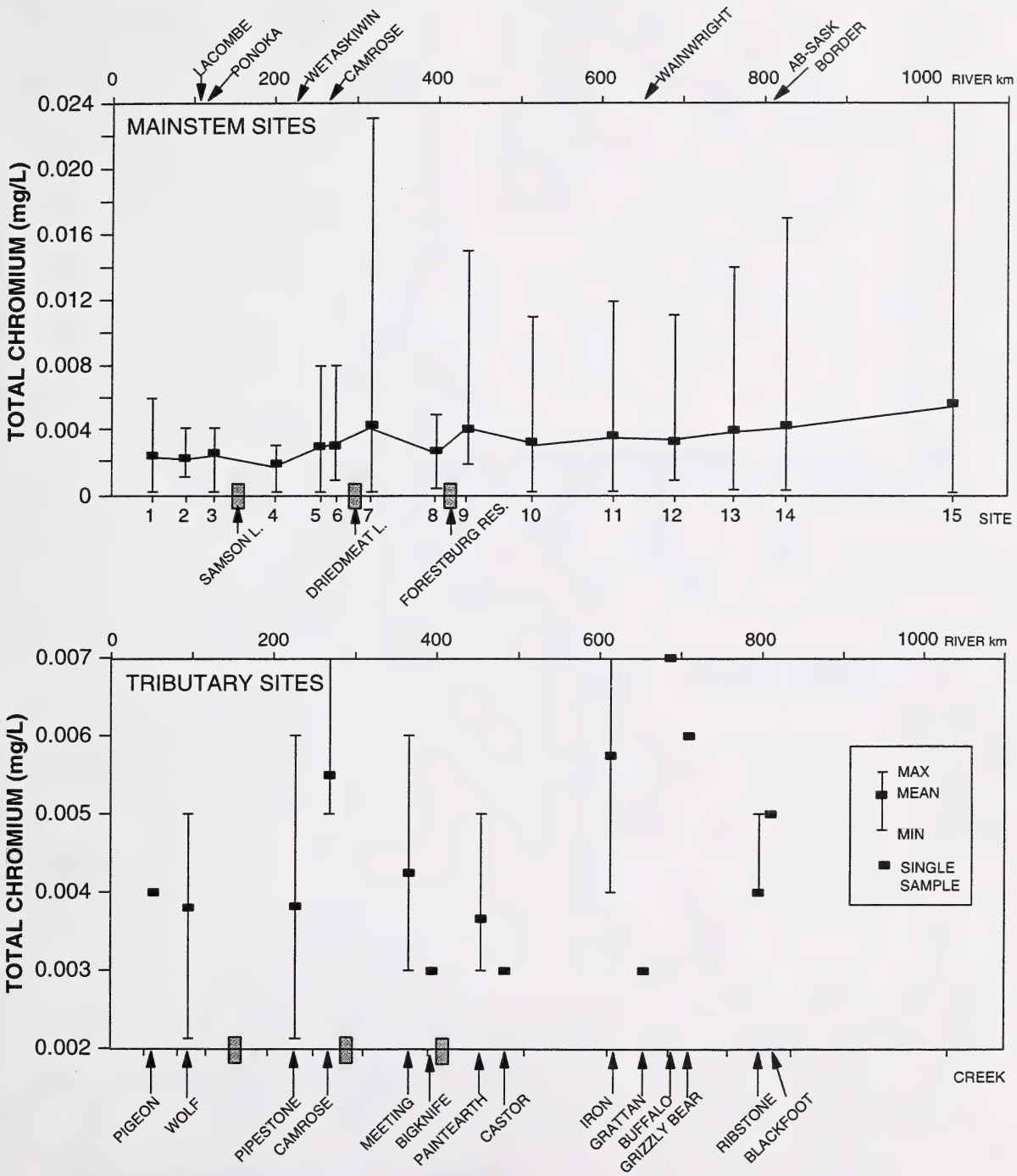


FIGURE 74. TOTAL CHROMIUM in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

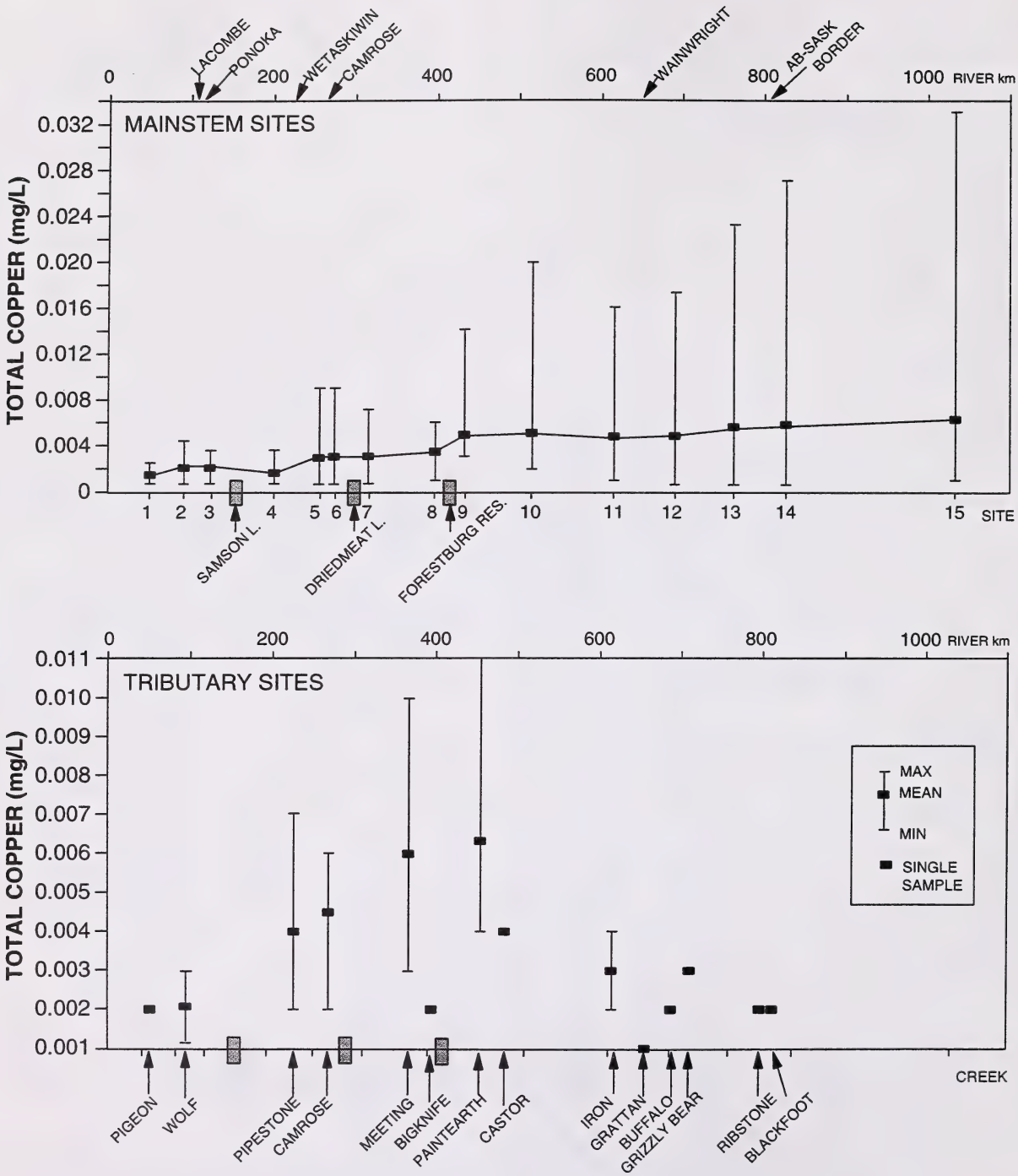
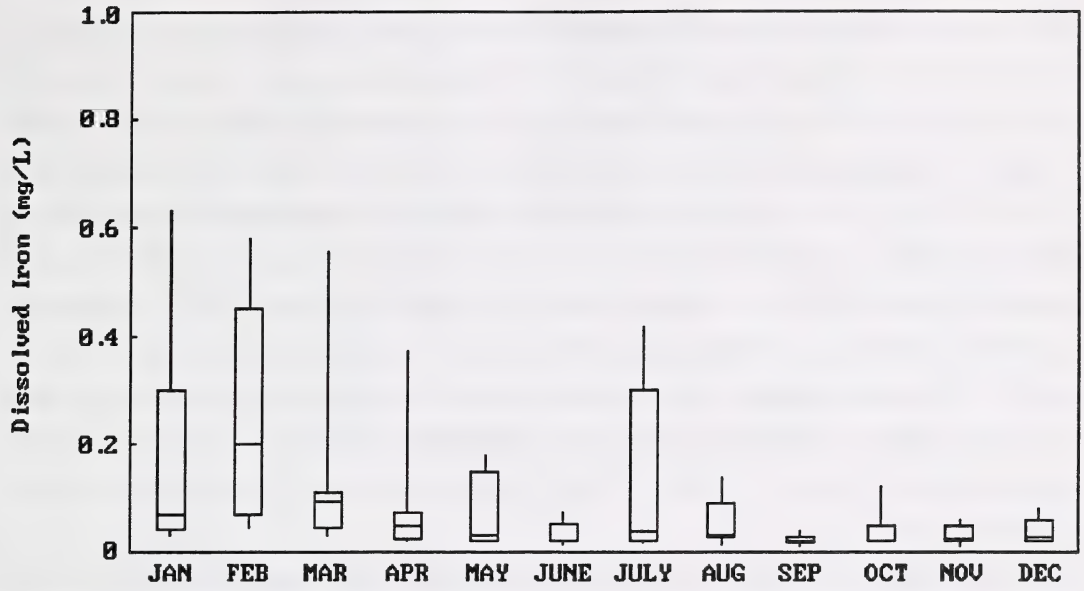


FIGURE 75. TOTAL COPPER in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).



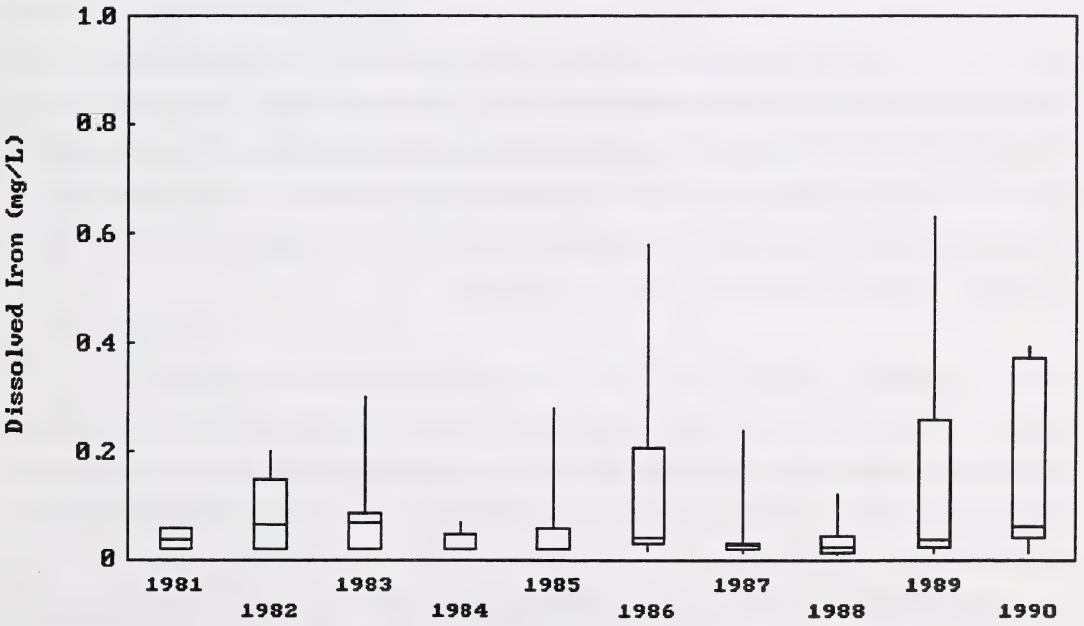


FIGURE 76. DISSOLVED IRON SEASONAL AND YEAR-TO-YEAR CHANGES AT UNWIN.

explain seasonal changes observed at mainstem and tributary sites sampled in 1989-1990 where high dissolved arsenic levels usually coincided with low dissolved iron levels.

In 1989-1990 average total arsenic concentrations increased gradually in a downstream direction and ranged from 0.0015 mg/L at site 1 (Highway 611) to 0.0872 mg/L at site 15 near the mouth (Figure 71). Highest total arsenic concentrations were measured during spring runoff when flows and NFR levels were highest. At that time most of the arsenic was in particulate form, but as flows declined the proportion of dissolved arsenic increased (Appendix 1). The seasonal pattern for dissolved arsenic described for long-term data at Unwin also applied to survey data.

Longitudinal changes in total arsenic levels in the Battle River were apparently unrelated to municipal discharges or inputs from the Alberta Power Ltd. coal-fired power plant. Tributaries contributed moderate amounts to the river. Therefore it is likely that most of the arsenic in the river originates from natural weathering.

AASWQIG of 0.01 mg/L total arsenic were exceeded once at each of the three lower sites (sites 13 to 15) during the April 1990 survey. All samples complied with the CWQG for the protection of aquatic life (0.05 mg/L).

Arsenic was also monitored in sediments and biota in 1989-1990 (Anderson et al. 1992). Arsenic levels in Battle River sediments exceeded the US EPA (1977) guidelines and occasionally exceeded the Ontario Ministry of the Environment guidelines (Persaud and Wilkins 1976). Concentrations of arsenic in roots of *Potamogeton richardsonii* were the only biological samples collected by Anderson et al (1992) which were above the concentration range for uncontaminated waters (Moore and Ramamoorthy 1984). All invertebrate samples contained much lower levels of arsenic than usually reported for aquatic environments which have been anthropogenically contaminated.

4.3.6.4 Barium

Barium is a common element in the earth's crust where it chiefly occurs as barite ($BaSO_4$). Weathering of barium minerals releases barium to surface waters, but normally only trace concentrations are found in aquatic systems. Barium has a wide range of industrial applications including the use of barite in drilling mud (CCREM 1987).

Total barium has been monitored at Unwin since 1980 and concentrations have not changed significantly over that period of time (Table 10).

In 1989-1990 average total barium concentrations increased gradually in a downstream direction from a minimum of 0.069 mg/L at site 4 (downstream of Samson Lake) to a maximum of

0.124 mg/L at site 15 near the mouth (Figure 72). At most sites, but especially those in the eastern portion of the basin, maximum barium concentrations were measured during the spring runoff survey in April 1990, when NFR concentrations and river flows were highest (Appendix 1). This suggests that flushing flows are required to re-suspend barium that has been removed from the water column by precipitation or sorption and sedimentation or that is associated with sediment particles.

Tributary concentrations in the western portion of the basin and as far downstream as Paintearth Creek had comparable barium levels to mainstem sites, but tributaries further downstream (excluding Ribstone Creek) had somewhat lower concentrations than nearby mainstem sites. Differences in geology likely account for differences in tributary concentrations. All samples collected in 1989-1990 and all long-term samples from Unwin met AASWQIG of 1.0 mg/L. There are no CWQG for barium.

4.3.6.5 Beryllium

Beryllium enters natural waters through weathering processes, atmospheric fallout, and discharges from industrial and municipal operations (CCREM 1987). It is a trace element that does not usually occur in natural waters, and environmental concentrations are usually less than 0.001 mg/L in fresh waters (McNeely et al. 1979).

Beryllium has not been monitored at the Unwin long-term site.

With the exception of one sample from site 15 (near the mouth) where 0.001 mg/L beryllium was measured, all Battle River mainstem and tributary samples analyzed in 1989-1990 had beryllium concentrations which were below the analytical detection limits of 0.001 mg/L (Appendix 1).

There are no AASWQIG or CWQG for beryllium.

4.3.6.6 Cadmium

Cadmium is not an abundant metal in the earth's crust (Forstner and Wittmann 1981). It enters surface waters through the weathering of cadmium-rich minerals, but background levels in natural surface waters are usually very low. Because of its multiple applications in the metal industries and in agriculture, anthropogenic contributions may be important (McNeely et al. 1979, CCREM 1987).

Total cadmium has been monitored at Unwin since 1980 and has been detected in less than 20% of the samples. Concentrations ranged from below the detection limit (0.0001 mg/L) to 0.0004 mg/L (Appendix 1).

In 1989-1990 cadmium levels in the Battle River and its tributaries ranged from <0.001 to 0.006 mg/L and the frequency of detections increased in a downstream direction.

The AASWQIG of 0.01 mg/L were met in all survey samples and all samples from the long-term site. The CWQG for the protection of aquatic life for the average hardness in the Battle River (i.e., hardness ≥150 mg/L) is 0.0013 mg/L. Although all long-term data complied with this guideline, many survey data from 1989-1990 did not. According to McNeely et al. (1979) and CCREM (1987) natural concentrations in freshwaters range from 0.001 to 0.010 mg/L and higher concentrations can be attributed to anthropogenic sources. Cadmium in the Battle River was always below this range.

Non-residual cadmium was detected in Battle River sediments at concentrations which ranged from <0.07 to 0.27 mg/kg dry weight (Anderson et al. 1992); and which were lower than those reported for North Saskatchewan River sediments (Shaw et al. 1992).

4.3.6.7 Chromium

Weathering of chromium-bearing minerals is the main natural process by which chromium is released into the environment. Various processes in the metal industry, coal and oil burning, and cement manufacturing may contribute chromium to the environment.

Total chromium has been monitored at Unwin since 1983. The concentration range recorded over that period of time is quite wide (<0.0003 to 0.0223 mg/L), mainly because of high records in 1990. Monthly maxima were nearly all recorded in that year (Figure 73) and median annual concentrations were much higher than in other years (Figure 73). Higher than average flows during the 1990 open water season (Section 3.3) could account for the resuspension of more particulate chromium than usual, but flows do not explain the higher January 1990 records made independently at Unwin in long-term and in longitudinal winter survey samples (Appendix 1).

During the 1989-1990 surveys, chromium levels ranged from <0.001 to 0.024 mg/L and average concentrations increased very gradually in a downstream direction (Figure 74). Concentrations below the detection limit were encountered at most sites on one or two occasions, often in late spring or fall (Appendix 1). Concentration maxima were usually measured during the high flow surveys in April 1990. The predominance of particulate chromium at that time suggests that chromium was sorbed onto re-suspended organic or inorganic particles.

All survey and long-term samples met AASWQIG of 0.05 mg/L. However, CWQG for the protection of aquatic life (0.002 mg/L) were frequently not met in these samples. Even the more lenient CWQG for the protection of fish (0.02 mg/L) were not met in two survey samples (downstream of Driedmeat Lake in October 1990, near the mouth in April 1990) and in one sample from the Unwin long-term data set (January 1990).

As for most other metals monitored in Battle River sediments, the longitudinal pattern for chromium was primarily influenced by the organic carbon content and particle size of the sediments, rather than by identifiable point sources (Anderson et al. 1992). However, chromium levels in Battle River sediments tended to be somewhat higher than in the North Saskatchewan River (Shaw et al. 1992). Chromium levels in invertebrate and fish samples were typical of unpolluted waters, but levels in macrophyte roots were slightly elevated (Moore and Ramamoorthy 1984).

4.3.6.8 Cobalt

Cobalt is released into the environment through the weathering of cobalt-rich minerals (CCREM 1987). Anthropogenic sources of cobalt include emissions from coal burning, cobalt additions to phosphate fertilizers, and municipal wastewater discharges (CCREM 1987).

Total cobalt has been monitored at Unwin since 1980. Changes in analytical methods have occurred during that time and the method detection limit has been lowered. Concentrations at Unwin ranged from <0.0005 to 0.003 mg/L and cobalt was detected in nearly 50% of the samples (Appendix 5).

During the 1989-1990 surveys cobalt was not detected at site 4 (downstream Samson Lake) or at mainstem and tributary sites upstream of that site. However, most mainstem and tributary samples taken downstream of site 4 contained measurable amounts of cobalt. The concentration range in survey samples was <0.001 to 0.017 mg/L and concentration maxima were usually recorded during the spring runoff survey of April 1990. Cobalt was mostly associated with organic or inorganic particles at that time (Appendix 1).

AASWQIG and CWQG for continuous irrigation, 0.05 mg/L cobalt, were met in all survey samples and all long-term samples. However, many of these samples were non-compliant with CWQG for the protection of aquatic life (0.002 mg/L).

Non-residual cobalt levels in Battle River sediments were in the range of 4.5 to 12.5 mg/kg dry weight. Concentrations were higher in the rich organic muds sampled at sites upstream of Driedmeat Lake than on sandy sediments low in organic carbon content sampled further downstream (Anderson et al. 1992). The cobalt concentration of Battle River sediments was well below 20 mg/kg, which is typical for freshwater sediments (CCREM 1987).

4.3.6.9 Copper

Copper is a common metallic element in the rocks and minerals of the earth's crust. Natural sources of copper in the aquatic environment include the weathering or the solution of copper minerals.

Natural background levels of copper in surface waters are usually well below 0.020 mg/L. As a result of the diverse use of copper, anthropogenic activities can release significant amounts to the environment.

Total copper has been monitored at Unwin since 1980 and levels have not changed significantly since that time (Table 10). Concentrations ranged from 0.0008 to 0.0410 mg/L and averaged 0.0052 mg/L (Appendix 5).

During the 1989-1990 surveys, average total copper concentrations increased in a downstream direction from 0.001 mg/L at site 1 (Highway 611) to 0.006 mg/L at site 15 near the mouth (Figure 75). Little seasonal variation was apparent in the data set except for the occurrence, at most sites, of high copper concentrations at spring runoff time (especially April 1990 survey). At that time most of the copper was in particulate form, whereas at other times dissolved copper was more abundant (Appendix 1).

The largest longitudinal increases occurred principally between site 4 and 5 and between site 7 and 9 (Figure 75). Some of these increases are at least in part due to tributary loads from Pipestone Creek and Meeting Creek (Table 11). These tributaries as well as Camrose and Paintearth Creek have notably higher copper concentration than most other tributaries in the basin (Figure 75). The most notable increase in average copper concentrations (1.5 µg/L) occurs in the Forestburg Reservoir (i.e., between site 8 and site 9). There are several possible causes for this increase (e.g., coal-burning or associated processes at Alberta Power Ltd. and naturally high background levels), all of which require further investigation to evaluate their relative importance. Sediment data provide another indication of local copper enrichment. Sediment samples from the Forestburg Reservoir had similar characteristics as the rich organic mud sampled upstream of Driedmeat Lake, but they contained twice as much copper (Anderson et al. 1992).

Water samples collected at the three lower survey sites (site 13 to 15) in April 1990 contained copper levels which exceeded the AASWQIG of 0.002 mg/L. AASWQIG were also exceeded by several samples collected at the long-term site. Most of these non-compliant copper levels were measured during periods of high river flow. CWQG for the protection of aquatic life (0.002 mg/L) were exceeded by many survey samples in the entire basin and by many long-term monitoring samples.

4.3.6.10 Iron

Iron is naturally released into the environment from the weathering of sulphide ores and igneous, sedimentary, or metamorphic rocks (CCREM 1987, McNeely et al. 1979). As a result of the many uses of iron, anthropogenic sources to the environment are diverse and include the burning of coal, sewage, landfill leachates, and corrosion of iron and steel (CCREM 1987).

Median concentrations of dissolved iron at Unwin have not changed since its monitoring started in 1981 (Table 10). However, maximum concentration records have increased over the years, much in the same way as for manganese (Figures 76 and 78). Seasonal changes are characterized by high winter concentrations followed by a rapid decline at ice break and persistent low concentrations during the rest of the open water season. This seasonal pattern in aquatic environments is largely explained by the chemical behaviour of iron which is primarily determined by oxidation-reduction reactions (CCREM 1987). In oxygenated conditions, ferric ions are prevalent; they form insoluble salts which precipitate. Soluble ferrous ions are formed under reducing conditions and they account for high dissolved iron concentrations over the winter.

In 1989-1990, average total iron concentrations increased gradually from 0.363 mg/L at site 1 to 4.006 mg/L at site 15 (Figure 77). At all sites maximum concentrations were measured in April 1990, at which time most iron was in particulate form associated with re-suspended organic and inorganic particles; concentrations as high as 28.7 mg/L were recorded in that survey, but at other times of year total iron levels were well below 1 mg/L.

Pipestone, Meeting and Paintearth creeks have higher iron levels than nearby mainstem sites and are important contributors to the overall river load (Table 11). However, tributaries in the lower portion of the basin have lower iron concentration and they contribute much less to the in-stream load.

Iron concentrations in the Battle River reflect the influence of surficial geology in the basin as well as natural in-stream processes. Anthropogenic loads are probably much less important than natural background loads. However, inasmuch as cultural eutrophication has influenced oxygen cycling, it has also affected iron cycling.

Many of the 1989-1990 survey data and long-term data from Unwin were non-compliant with the CWQG for freshwater aquatic life and with the AASWQIG and the PPWBO which recommend 0.3 mg/L as an upper limit.

4.3.6.11 Lead

The principal natural pathway by which lead is released into the environment is weathering of sulphide ores. The levels of dissolved lead in natural surface waters are generally low, but can be increased significantly by anthropogenic inputs. Gasoline-powered motors has represented the major source of lead to the environment in the past, although industrial sources can also be important. Lead enters aquatic systems through atmospheric deposition and runoff.

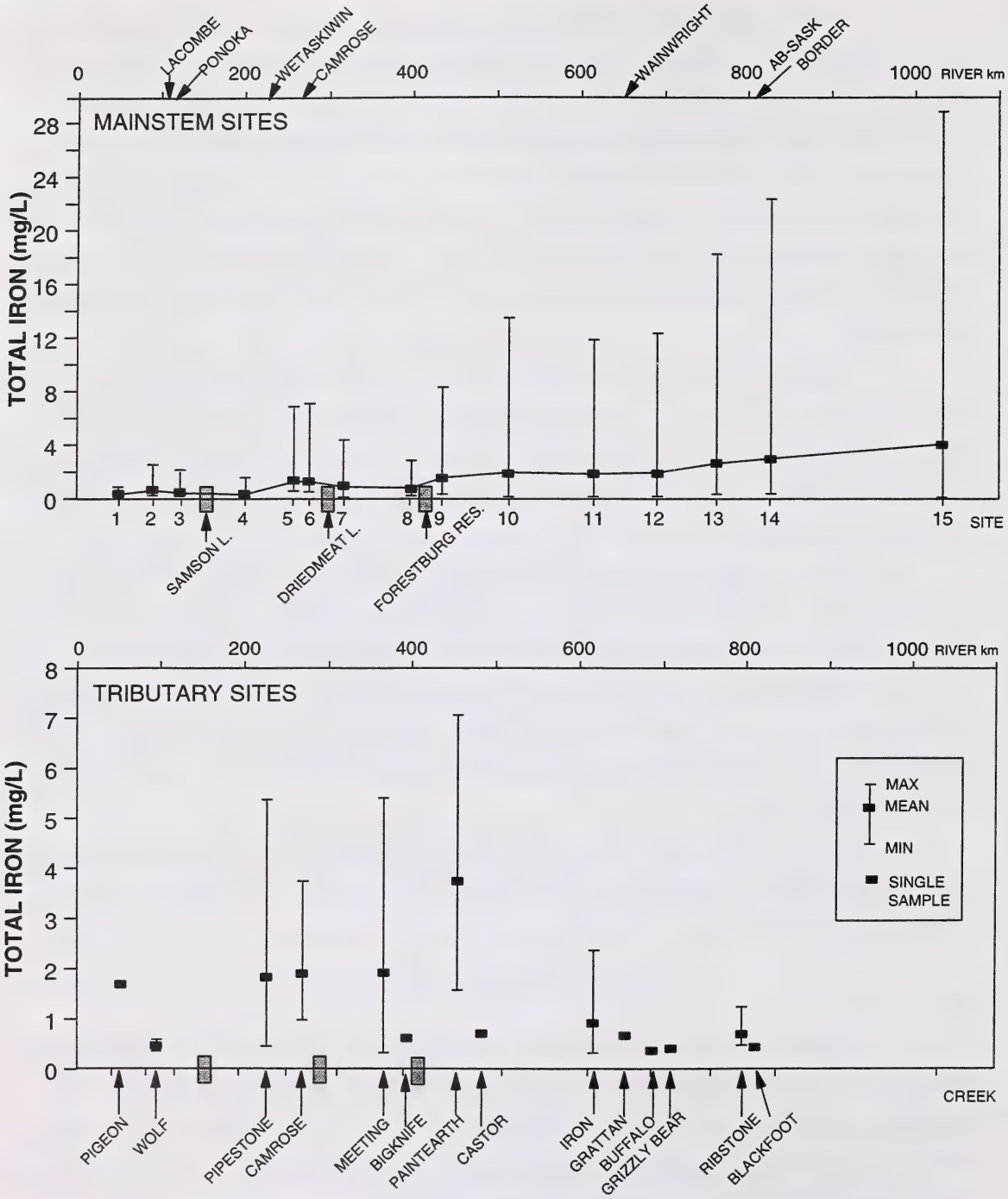


FIGURE 77. TOTAL IRON in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

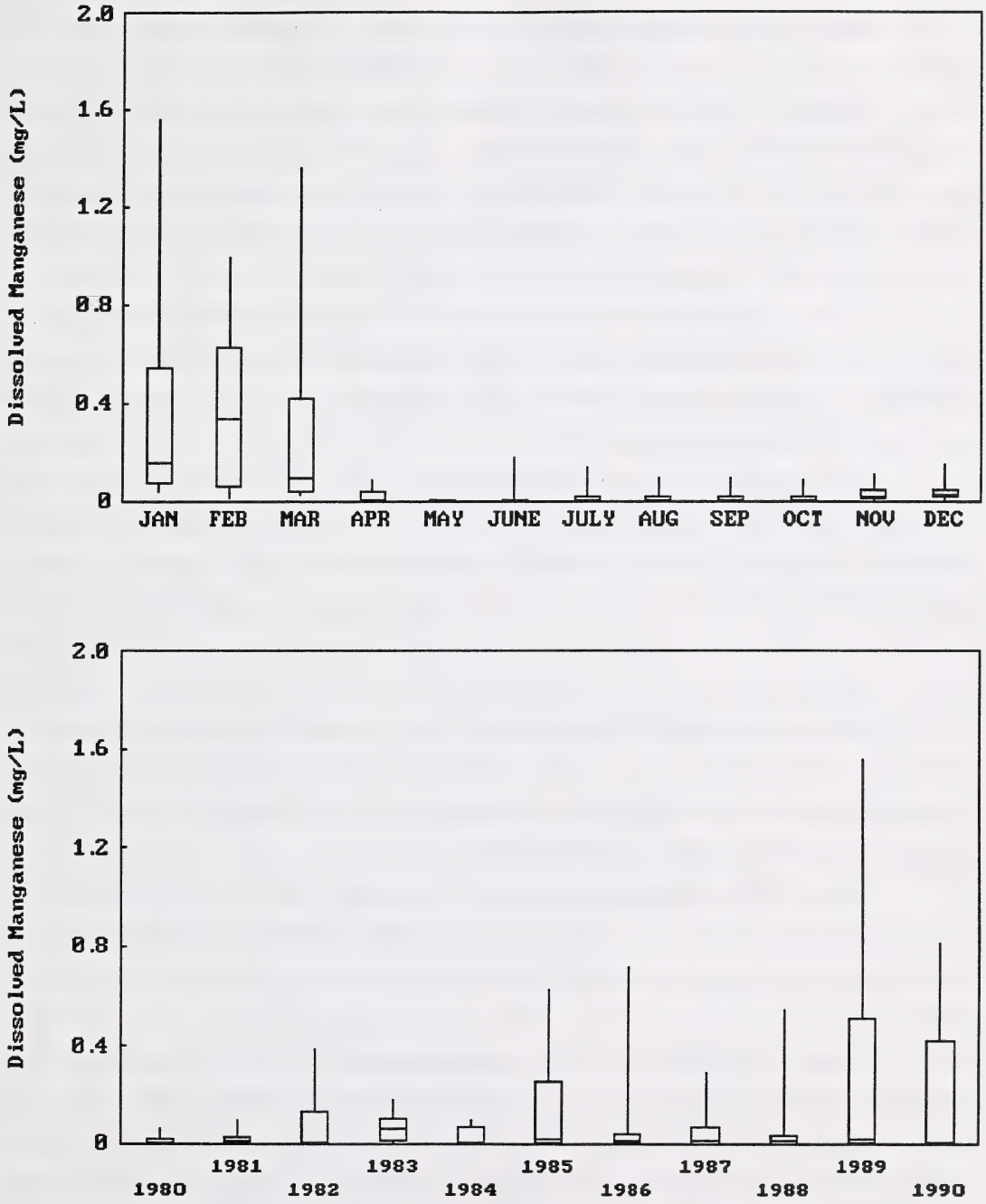


FIGURE 78. DISSOLVED MANGANESE-SEASONAL AND YEAR-TO-YEAR CHANGES AT UNWIN.

Total lead has been monitored at Unwin since 1980 and has been detected in 40% of the samples. Concentrations in the long-term data set ranged from <0.0007 to 0.0550 mg/L (Appendix 5).

During the 1989-1990 surveys, extractable lead was detected in 16% (i.e., 34 samples) of all samples; detectable concentrations ranged from 0.002 to 0.013 mg/L (Appendix 1). Highest concentrations were usually recorded at times when NFR levels were also high (i.e., April 1990). The lead concentrations recorded in survey and long-term data from the Battle River fall within the concentration range for lead in western Canadian surface waters (CCREM 1987).

Of the 34 times that lead was detected in the 1989-1990 surveys, PPWBO (0.007 mg/L) and CWQG for the protection of aquatic life (0.002 mg/L) were exceeded 4 and 11 times, respectively. AASWQIG (0.05 mg/L) were met in all survey samples. Long-term data from Unwin were non-compliant once with AASWQIG and 10 times with CWQG.

Lead in Battle River sediments ranged from 2 to 12 mg/kg (dry weight), concentrations were lowest near the headwaters (Highway 611) and on the sandy substrates sampled at Unwin. Although some anthropogenic enrichment is suspected, lead levels in Battle River sediments were lower than in sediments from the North Saskatchewan River (Shaw et al. 1992) or from other Canadian rivers (CCREM 1987).

4.3.6.12 Manganese

Manganese is widely distributed in the earth's crust and soils; sediments, metamorphic and sedimentary rocks are significant natural sources. Anthropogenic sources to surface waters are primarily industrial and include iron and steel industries and acid mine drainage (CCREM 1987). None of these three sources is potentially important in the Battle River basin.

Dissolved manganese has been monitored at Unwin since 1980. Over that period of time average annual concentrations have not changed significantly (Table 10), but maximum annual concentrations have increased notably over the years much in the same way as for iron (Figures 78 and 76). Dissolved manganese at Unwin exhibits a distinct seasonal pattern characterized by high winter concentrations (up to 1.56 mg/L), followed by a spectacular decline in spring (concentrations often <0.002 mg/L) and a very gradual increase in concentrations over the rest of the year (Figure 78). Such pronounced changes in dissolved manganese are not uncommon in aquatic environments where redox potential, dissolved oxygen, pH and organic matter fluctuate drastically (CCREM 1987). Under reducing conditions dissolved manganese predominates, but it is readily oxidized too less soluble forms which precipitate (CCREM 1987).

During the 1989-1990 surveys there was a gradual increase in total manganese levels in a downstream direction. Average concentrations ranged from 0.050 mg/L at site 4 to 0.280 mg/L at site 15 (Figure 79). Individual concentrations ranged from 0.016 mg/L to 0.914 mg/L. Concentration maxima were generally recorded in April 1990 at spring runoff. At that time manganese, was mostly associated with particulate suspended material (Appendix 1). For three sites concentration maxima were not recorded in April 1990, but in February (Highway 53, near mouth) or October (downstream of Driedmeat Lake). The dominance of dissolved over particulate manganese in these samples is related to the reducing conditions which prevailed at these sites at the time of sampling (see Section 4.3.3).

AASWQIG and PPWBO (both 0.05 mg/L) and CWQG for irrigation water (0.2 mg/L) were exceeded at all sites by average concentrations and/or by individual measurements. Non-compliance with these guidelines was most frequent at high river flows, in spring and under reducing conditions.

4.3.6.13 Mercury

Mercury is fairly widely distributed in the environment. It occurs in most types of rocks and is also present in the atmosphere. Approximately 80% of the mercury that enters aquatic ecosystems on a global scale comes from natural sources (CCREM 1987). However, anthropogenic sources can be ecologically more significant than natural sources in local regions (CCREM 1987).

Since 1979, total mercury has been detected in nearly 20% of Unwin samples at concentrations ranging from 0.01 to 0.07 µg/L.

Eight samples (i.e., 4% of total) collected during the 1989-1990 surveys contained measurable amounts of mercury. One sample from Camrose Creek (October 1990) and one from Meeting Creek (October 1990) contained 0.2 µg/L mercury; all remaining detections were 0.1 µg/L.

AASWQIG, PPWBO and CWQG for the protection of aquatic life recommend maximum mercury concentrations of 0.1 µg/L. This value was exceeded in two survey samples, but all long-term samples complied.

Sediment type strongly influenced mercury concentrations in Battle River sediments (Anderson et al. 1992). The rich organic mud sampled at Highway 611, Highway 53 and downstream of Camrose Creek contained 0.007 to 0.020 mg/kg wet weight of mercury, whereas the sandy sediments of Highway 872, Unwin, and near the mouth had lower levels ranging from <0.002 to 0.006 mg/kg wet weight. These values are lower than in the North Saskatchewan River where concentrations as high as 0.1 mg/kg were reported (Shaw et al. 1992). Battle River sediment mercury concentrations complied with

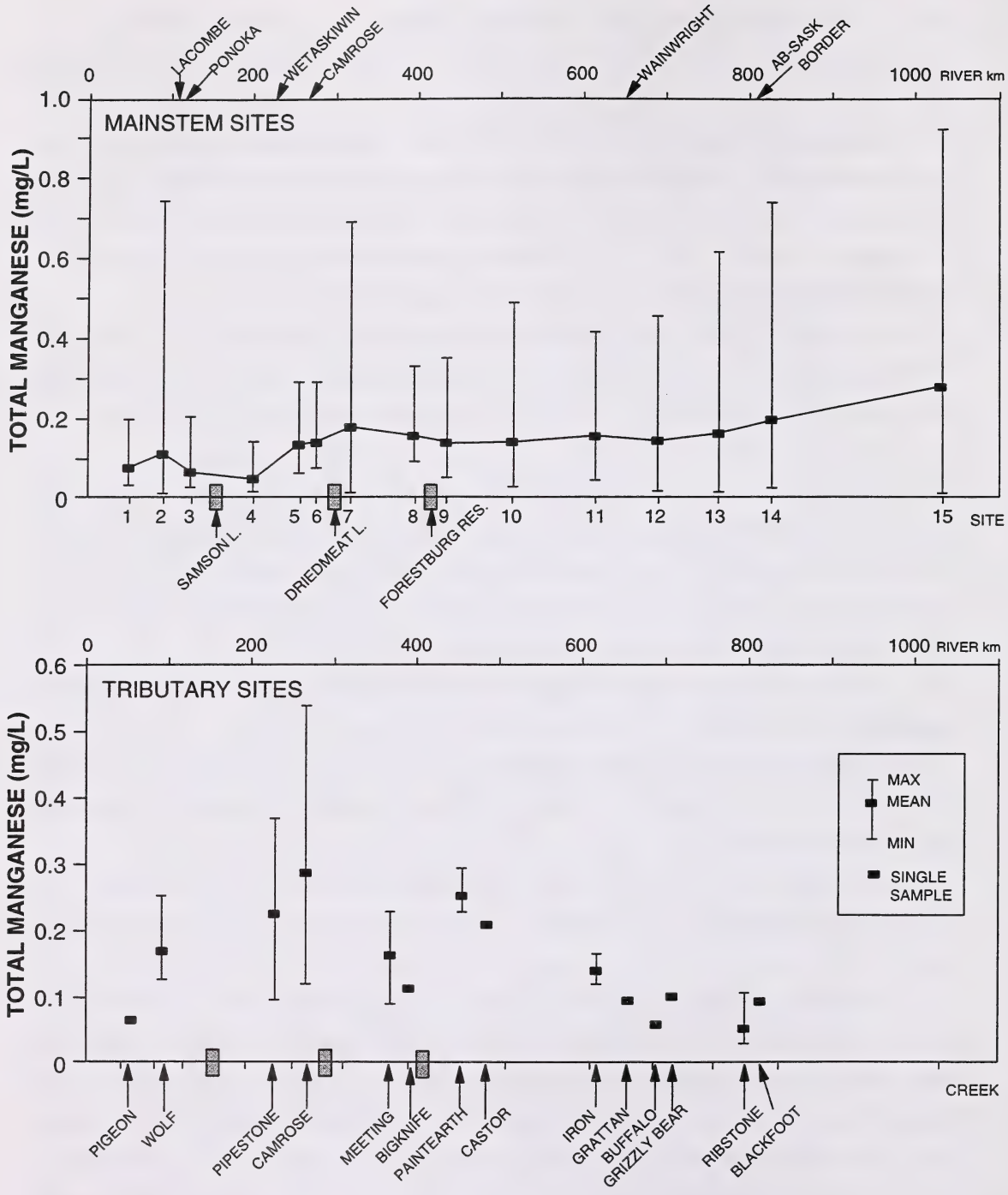


FIGURE 79. TOTAL MANGANESE in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

the guideline proposed by the Ontario Ministry of the Environment (Persaud and Williams 1976) for dredge spoil disposal (0.3 mg/kg mercury).

Mercury is of particular concern in the environment because it biomagnifies along the food chain (e.g., Campbell et al. 1988). Consequently, concentrations potentially harmful to human health can accumulate in fish, even if concentrations in water are quite low. In the Battle River, mercury was detected more often and at higher levels in fish than in other biota (Anderson et al. 1992). Muscle sample from northern pike and white suckers taken from the Forestburg Reservoir contained 0.103 to 0.341 mg/kg mercury (wet weight). All samples complied with guidelines for unlimited consumption (0.5 mg/kg) adopted by the Joint FAO/WHO Expert Committee on Food Additives (1972).

4.3.6.14 Molybdenum

Molybdenum is widely distributed in nature and the weathering of igneous and sedimentary rocks constitutes an important natural source of molybdenum to the aquatic environment. Molybdenum has a wide range of modern applications; among these the use of fertilizers containing molybdenum represents the largest anthropogenic input to the aquatic environment (CCREM 1987).

Molybdenum is not monitored at Unwin.

In 1989-1990 average molybdenum concentrations increased gradually in a downstream direction from about 0.001 mg/L at site 1 to 0.004 mg/L at site 15. Individual concentrations ranged from <0.001 mg/L to 0.015 mg/L. At most sites concentration maxima were recorded in April 1990 when NFR and flows were also highest (Figure 80). Tributary concentrations are similar to those at mainstem sites (Appendix 1). In-stream concentrations suggest that natural geochemical processes and diffuse sources are more important contributors than point sources.

There are no AASWQIG or PPWBO for molybdenum and CWQG apply only to irrigation water (0.05 mg/L). All survey samples from 1989-1990 were well below that guideline.

4.3.6.15 Nickel

Nickel enters the environment primarily through the weathering of minerals and rocks and as a result of human activity, especially fossil fuel burning (CCREM 1987).

Total nickel has been monitored since 1980 at the Unwin long-term station and concentrations have not changed significantly over these years of monitoring (Table 10). Seasonal changes are typified by high median concentrations in April at spring runoff time, a steady decline over the rest of the open-water season, and low winter values (Figure 81).

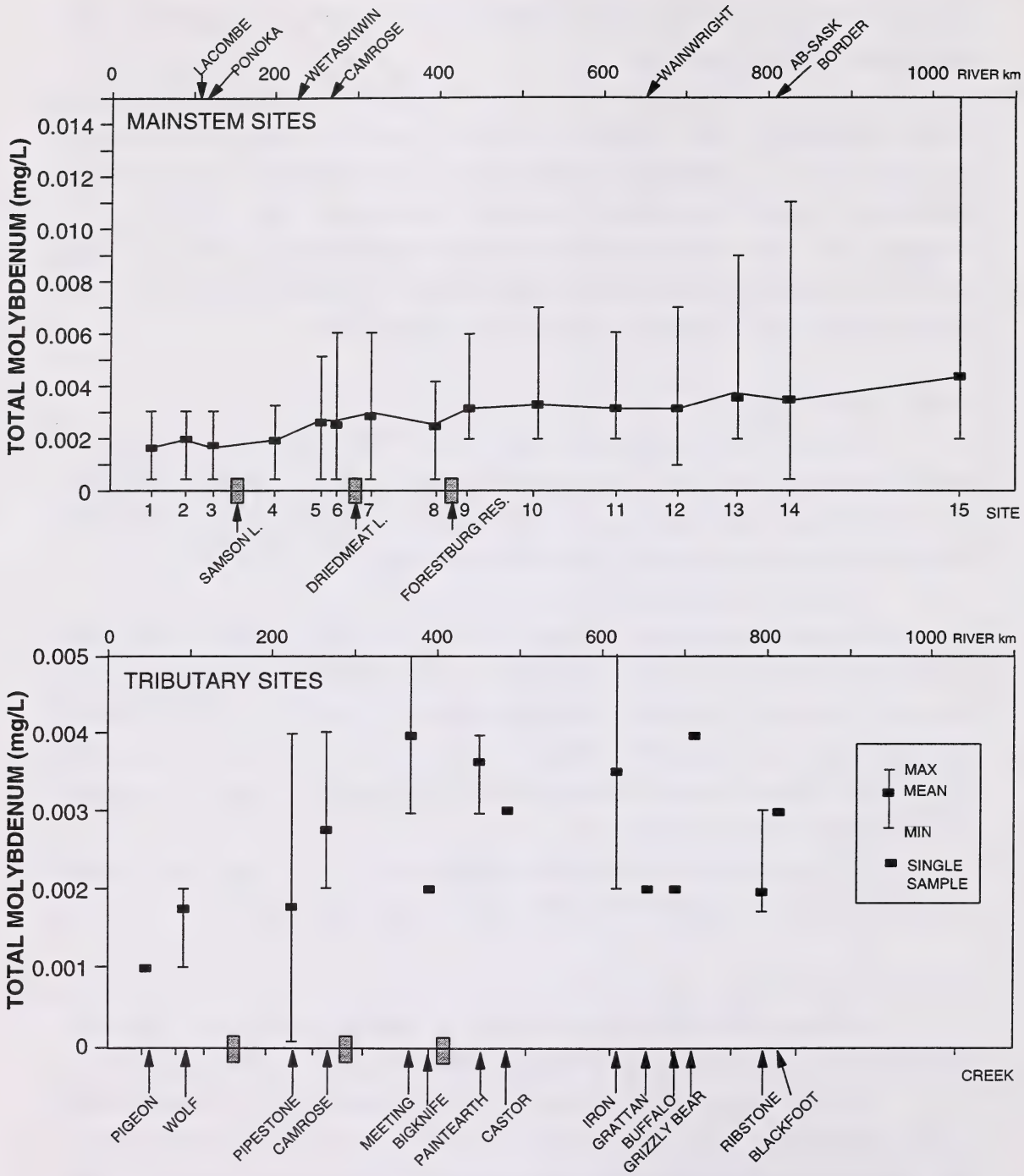


FIGURE 80. TOTAL MOLYBDENUM in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

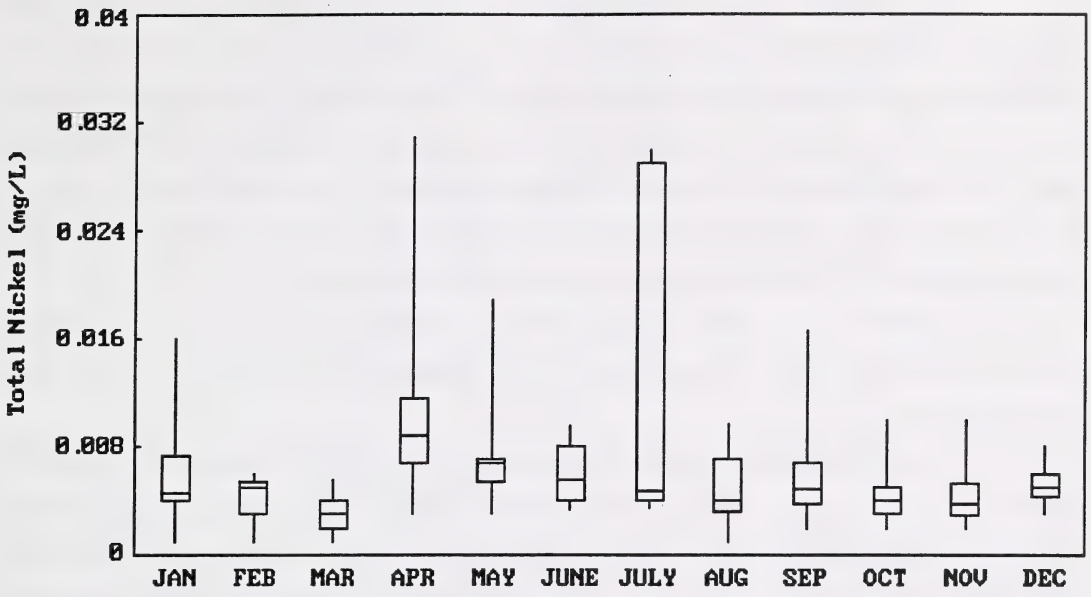


FIGURE 81. TOTAL NICKEL SEASONAL CHANGES AT UNWIN (1980 - 1990)

In 1989-1990 average nickel concentrations increased in a downstream direction from 0.002 mg/L at Highway 611 (site 1) to 0.011 mg/L near the mouth at site 15 (Figure 82). These concentrations are well within the concentration range for nickel in western Canadian surface waters. However, it is of interest that more than half of the total longitudinal increase occurred in two localized areas: downstream of Pipestone Creek (site 4 to 5) and downstream of the Forestburg Reservoir (site 8 to 9). Pipestone Creek has higher nickel levels than the Battle River (Figure 82) and because of its relatively large size compared to that of the river it acts as a major point source of nickel.

CWQG for the protection of aquatic life vary according to hardness. The most restrictive guideline for the Battle River (0.065 mg/L) was met by all samples collected in 1989-1990 surveys and at the long-term site.

Longitudinal patterns of nickel concentrations in Battle River sediments were defined by sediment characteristics rather than by point sources (Anderson et al. 1992). Nickel sediment concentrations ranged from 3 to 36 mg/kg dry weight and were similar to those reported for the North Saskatchewan River (Shaw et al. 1992). Nickel concentrations were higher in aquatic plants (1.0-16.5 mg/kg dry weight) than in invertebrates (0.1-13.0 mg/kg dry weight) which in turn were higher than in fish (<0.1 mg/kg dry weight). This is compatible with findings from other researchers who have documented highest bioconcentration factors in aquatic plants and lowest factors in fish (CCREM 1987).

4.3.6.16 Selenium

Selenium is widely distributed in the earth's crust and trace amounts occur naturally in water as a result of erosion of soils and weathering of rocks (CCREM 1987).

Dissolved selenium has been monitored at Unwin since 1974. As a result of the lowering of the analytical detection limit in 1983 (from 0.0005 to 0.0001 mg/L) the frequency of detection has increased from 3% to 90%. The highest dissolved selenium concentration measured at Unwin was 0.0006 mg/L.

Although concentrations were often below the analytical detection limit (0.0001 mg/L), total selenium was detected at least once at all sites sampled in 1989-1990 (Appendix 1). Both frequency of detection and concentration range increased in a downstream direction and the highest concentration 0.0006 mg/L was recorded at Unwin in April 1990. Selenium was also detected in many tributary samples, but concentrations were somewhat lower than at mainstem sites; Blackfoot Creek had the highest record with 0.0003 mg/L total selenium.

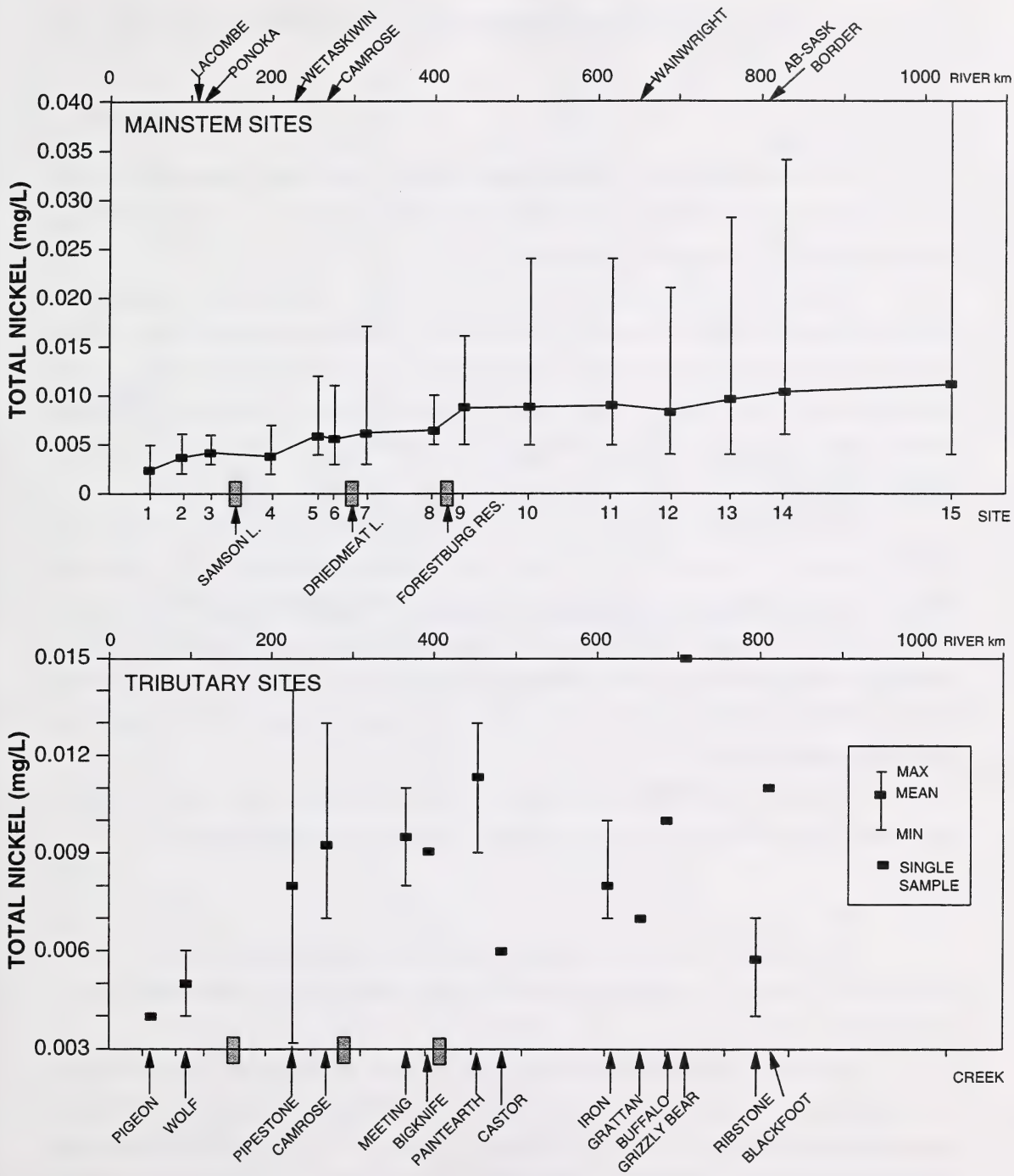


FIGURE 82. TOTAL NICKEL in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

All survey and long-term samples complied with the PPWBO and the CWQG of 0.001 mg/L for the protection of aquatic life.

4.3.6.17 Vanadium

Atmospheric deposition, and leaching from coal mining waste dumps, and coal ash are only a few of the many pathways by which vanadium enters the environment; according to CCREM (1987), by far the greatest amount is released by surface erosion.

Vanadium has been monitored at Unwin since 1980 and median concentrations have not changed significantly over the first 10 years of record (Table 10). The influence of river flow on vanadium concentrations is reflected in the seasonal pattern which is characterized by low median winter concentrations and highest values at spring runoff (Table 9, Figure 83). Vanadium concentrations averaged 0.0029 mg/L and ranged from the detection limit of 0.0005 mg/L to 0.0300 mg/L in the long-term data set at Unwin.

In 1989-1990 total vanadium increased gradually in a downstream direction from an average of 0.003 mg/L at site 1 (Highway 611) to 0.068 mg/L at site 15 near the mouth (Figure 84). In tributaries as well as at mainstem sites maxima in concentrations coincided with high flows and NFR levels at spring runoff. At that time vanadium occurred principally in particulate form whereas during periods of low to moderate flow the dissolved fraction was prevalent (Appendix 1). As for several other metals, Pipestone Creek contributed considerably to in-stream loads and there was a notable increase in loads downstream of the Forestburg Reservoir (Table 11).

There are no AASWQIG for vanadium. CWQG and PPWBO of 0.1 mg/L for livestock watering and irrigation water were met easily in all survey samples and in all long-term samples.

4.3.6.18 Zinc

Zinc can enter the environment through both natural and anthropogenic processes. Among these, weathering, primary zinc production, and municipal wastewater are the most important contributors (CCREM 1987).

Total zinc concentrations have not changed significantly at Unwin since 1980 (Table 10). As for many other metals, flow dependency (Table 9) and association of zinc with suspended particles explain much of the seasonal variability in the long-term data set. Typically, low median winter concentrations are followed by peak median concentrations during spring runoff and by a subsequent gradual decline

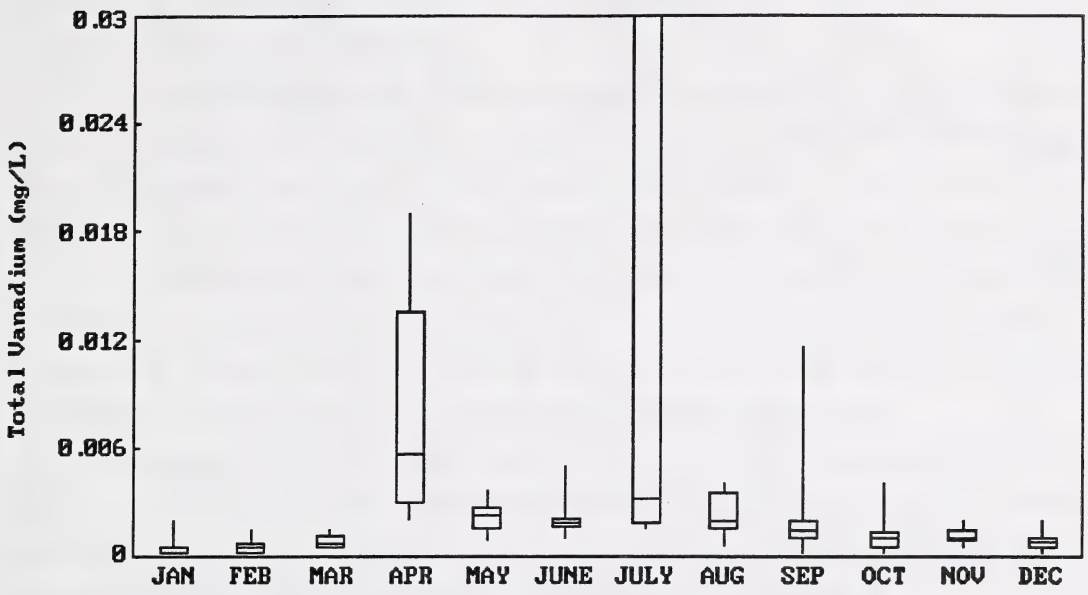


FIGURE 83. TOTAL VANADIUM SEASONAL CHANGES AT UNWIN (1980 - 1990)

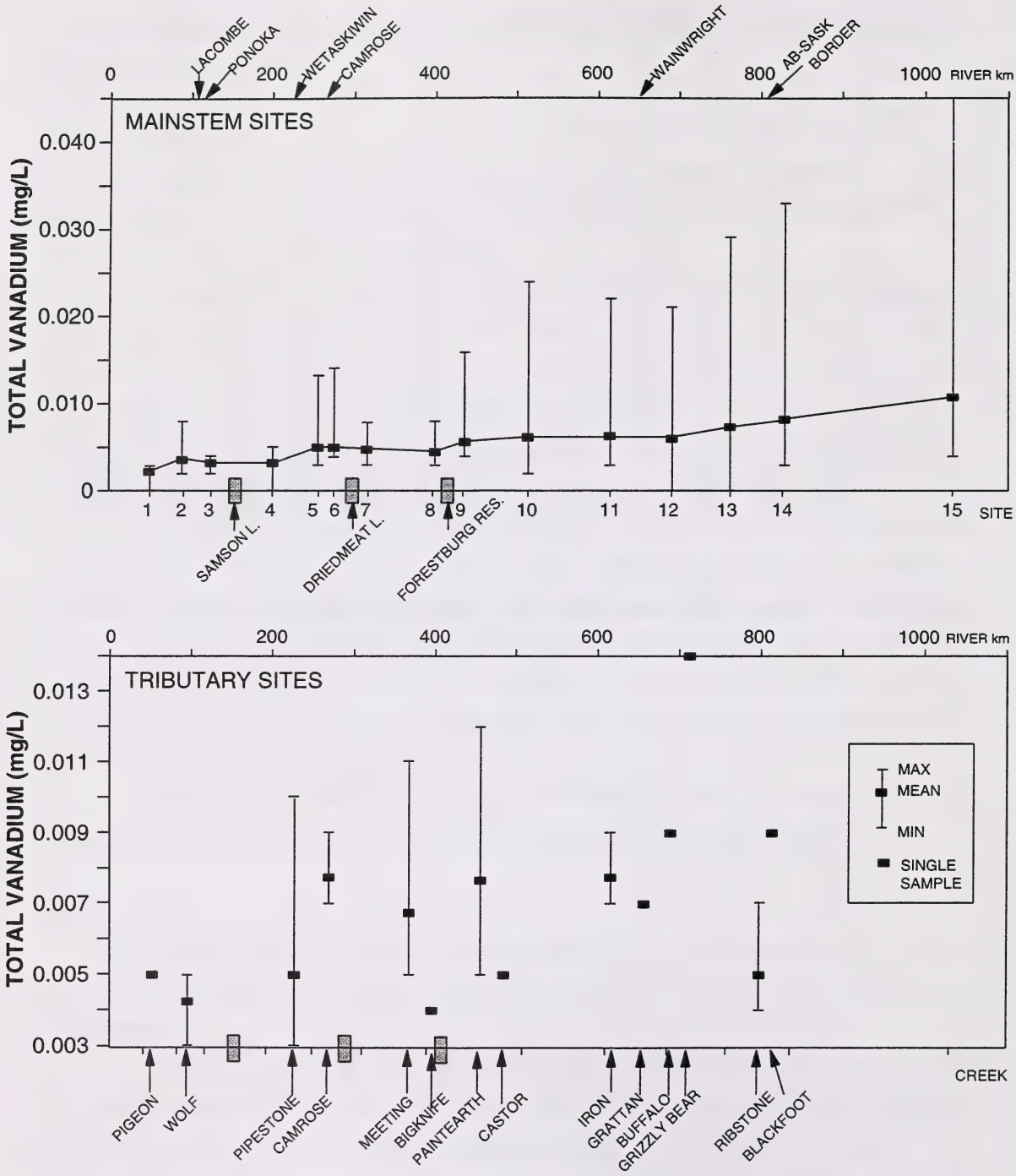


FIGURE 84. TOTAL VANADIUM in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

Figure 85). In the long-term data set concentrations averaged 0.0071 mg/L and ranged from below the detection limit, 0.001 mg/L to 0.056 mg/L.

In 1989-1990 average zinc levels increased gradually from 0.003 mg/L at site 1 (Highway 611) to 0.014 mg/L at site 15 near the mouth (Figure 86). Pipestone, Camrose, Meeting and Paintearth Creek had somewhat higher total zinc levels than most other tributaries or nearby mainstem sites. Pipestone Creek, in particular, was an important contributor of zinc to the Battle River (Table 11).

During the spring runoff survey of April 1990 total zinc levels exceeded PPWBO and CWQG (0.03 mg/L) for the protection of aquatic life and AASWQIG (0.05 mg/L) at all sites downstream of Camrose Creek. However, samples collected at other times were compliant. Non-compliance in the long-term data set was also generally associated with high river flows and high NFR levels.

Anderson et al. (1992) reported higher zinc levels in rich organic sediments sampled at sites upstream of Driedmeat Lake than on the sandy substrates sampled downstream of the Forestburg Reservoir, and found that zinc levels in a variety of aquatic invertebrates, macrophytes and fish were all below levels reported from polluted environments (Moore and Ramamoorthy 1984).

4.3.7 Biological Variables

4.3.7.1 Bacteria

Coliform bacteria are widely used as indicators of the presence of warm-blooded animal wastes and the potential of exposure to pathogenic organisms associated with these wastes. However, counts do not correlate well with the incidence of gastrointestinal illness and the test is being phased out in favour of more specific indicators (CCREM 1987). The coliform bacteria group is still monitored routinely in water quality studies because of ease of sampling and sample processing, and because there are water quality guidelines and a broad base of data for comparison. The total coliform test is non-specific and is a measure for all coliforms. Many coliforms are ubiquitous in the environment; they are common in both soil and water and can multiply outside the intestinal tract. Although they are not a reliable indicator of fecal contamination, coliforms are used as a general indicator of bacterial contamination in drinking water (CCREM 1987). The presence of fecal coliforms indicates fecal contamination. However, fecal coliforms can be found in feces of humans and aquatic or terrestrial animals such as livestock, birds, beaver, and muskrats.

In 1989-1990, total coliform counts were extremely variable in the Battle River, especially upstream of the Forestburg Reservoir (Figure 87). Highest counts in that portion of the river were recorded in spring, particularly during the April 1990 survey conducted at spring runoff time. The much lower total

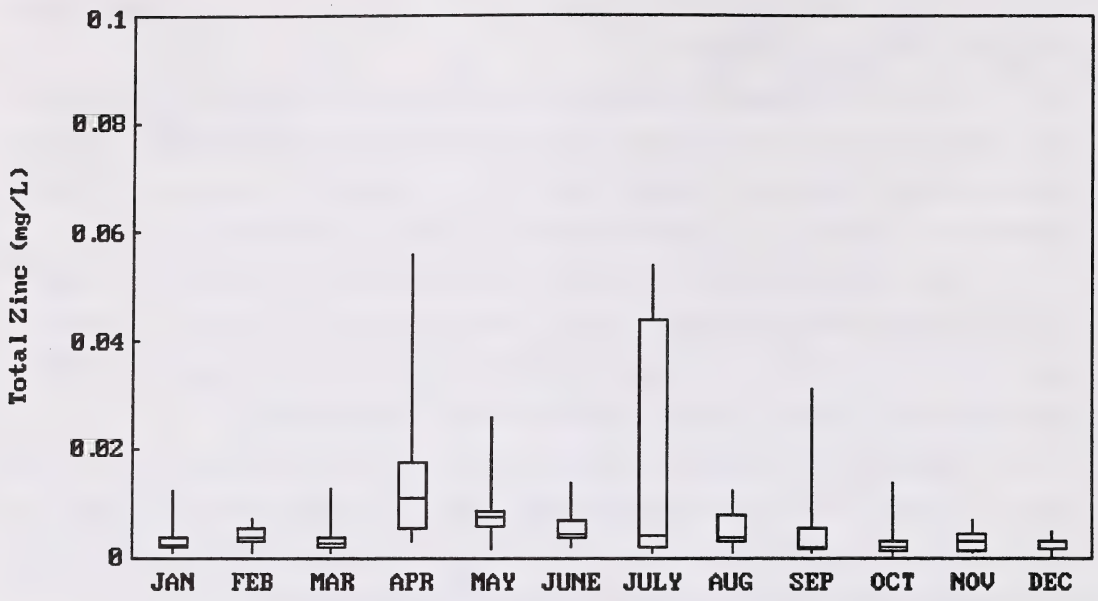


FIGURE 85. TOTAL ZINC SEASONAL CHANGES AT UNWIN (1980 - 1990).

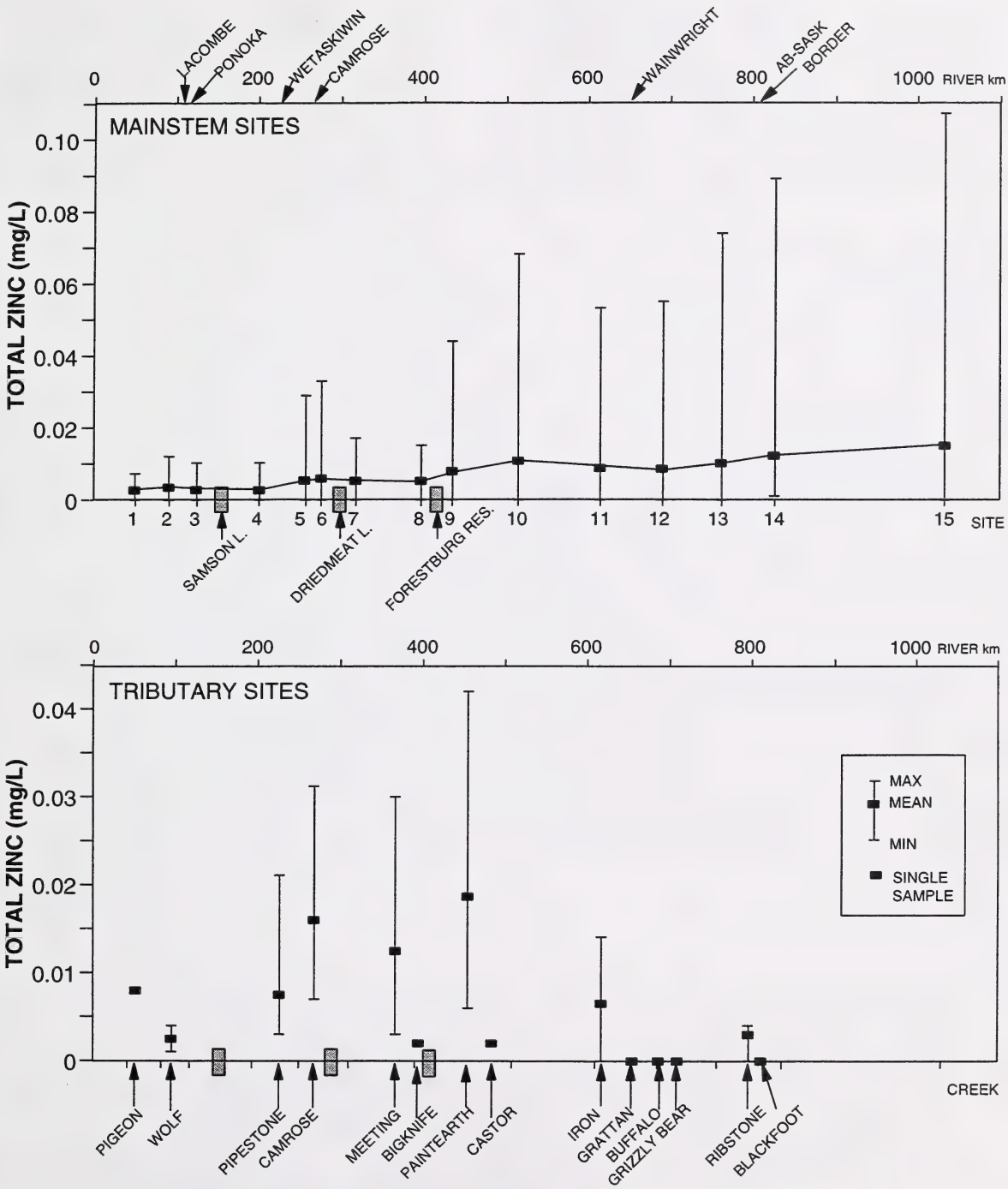


FIGURE 86. TOTAL ZINC in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

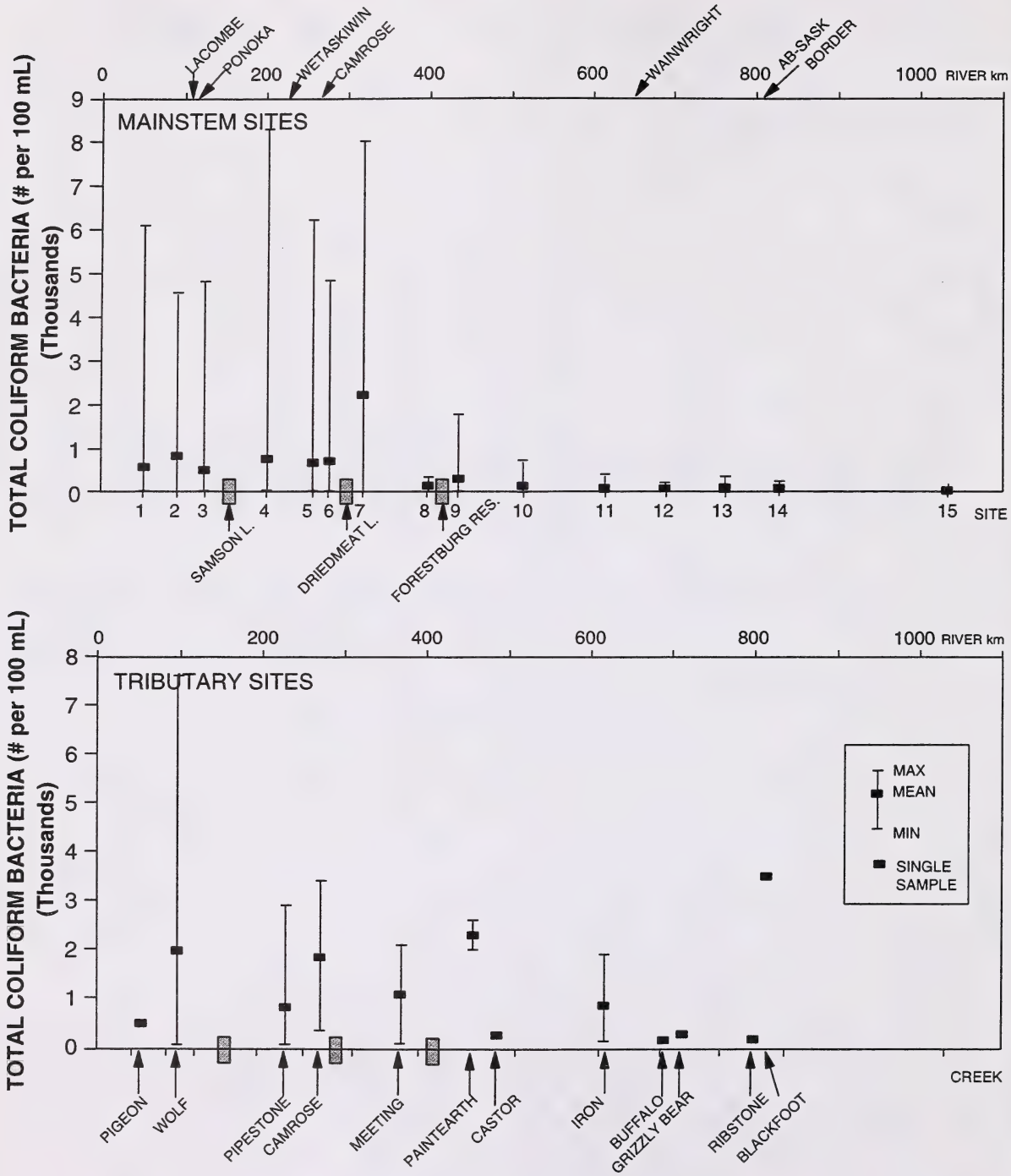


FIGURE 87. TOTAL COLIFORM BACTERIA in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

coliform counts shown in Figure 87 for sites downstream of the Forestburg Reservoir may not be truly representative of conditions in that area. For many of these sites (i.e., site 11 to 15), April 1990 samples became overgrown by non-coliform bacteria during the incubation process and had to be discarded. This data gap probably resulted in an underestimate of overall total coliforms in that area. However, long-term data from Unwin (Figure 88) suggest that total coliform counts do not increase as much at runoff time as they do in the upper portion of the basin.

Fecal coliform counts were generally less variable than total counts and extremes ranged from less than 4 to nearly 200 per 100 mL throughout the basin, except for one July 1989 sample downstream of Driedmeat Lake with very high counts (Figure 89). Seasonality in the survey samples and at the long-term site (Figure 88) was typified by low counts under ice and highest counts during the summer.

Tributary levels of fecal and total coliforms were similar to those at nearby mainstem sites (Figure 87, 89). There was no consistent relationship between wastewater discharges and increases in in-stream bacterial counts at tributary or mainstem sites (Appendix 1, Figure 2). This suggests that total and fecal coliform levels in the Battle River are more influenced by diffuse than point sources.

AASWQIG for contact recreation specify that total coliform counts should not exceed 2400 per 100 mL in any one sample. This objective was not met by most samples collected at runoff time in the upper portion of the basin. The CWQG of 10 total coliforms per 100 mL applies to treated drinking water and is irrelevant to the Battle River. The CWQG for contact recreation specifies that the geometric mean of at least 5 fecal coliform samples taken over not more than 30 days should not exceed 200 per 100 mL. Survey samples were not sampled according to this protocol, but the results indicate that guidelines were likely met most of the time. The PPWBO for fecal coliforms applies to irrigation water and recommends a maximum count of 100 per 100 mL. That objective was exceeded by maxima recorded at all sites, but averages complied.

4.3.7.2 Primary Producers

Macrophytes, and planktonic and periphytic algae are conspicuous in most of the Battle River.

In 1984 Fernet et al. (1985) documented macrophyte density in the Battle River as part of a fish habitat survey in the river stretch between Pipestone Creek and the Alberta border. By mid-summer macrophytes were very abundant between Pipestone Creek and Driedmeat Lake and they choked the river downstream of Driedmeat Lake. Although also very abundant at some locations they tended to be more patchy in their distribution downstream of the Forestburg Reservoir.

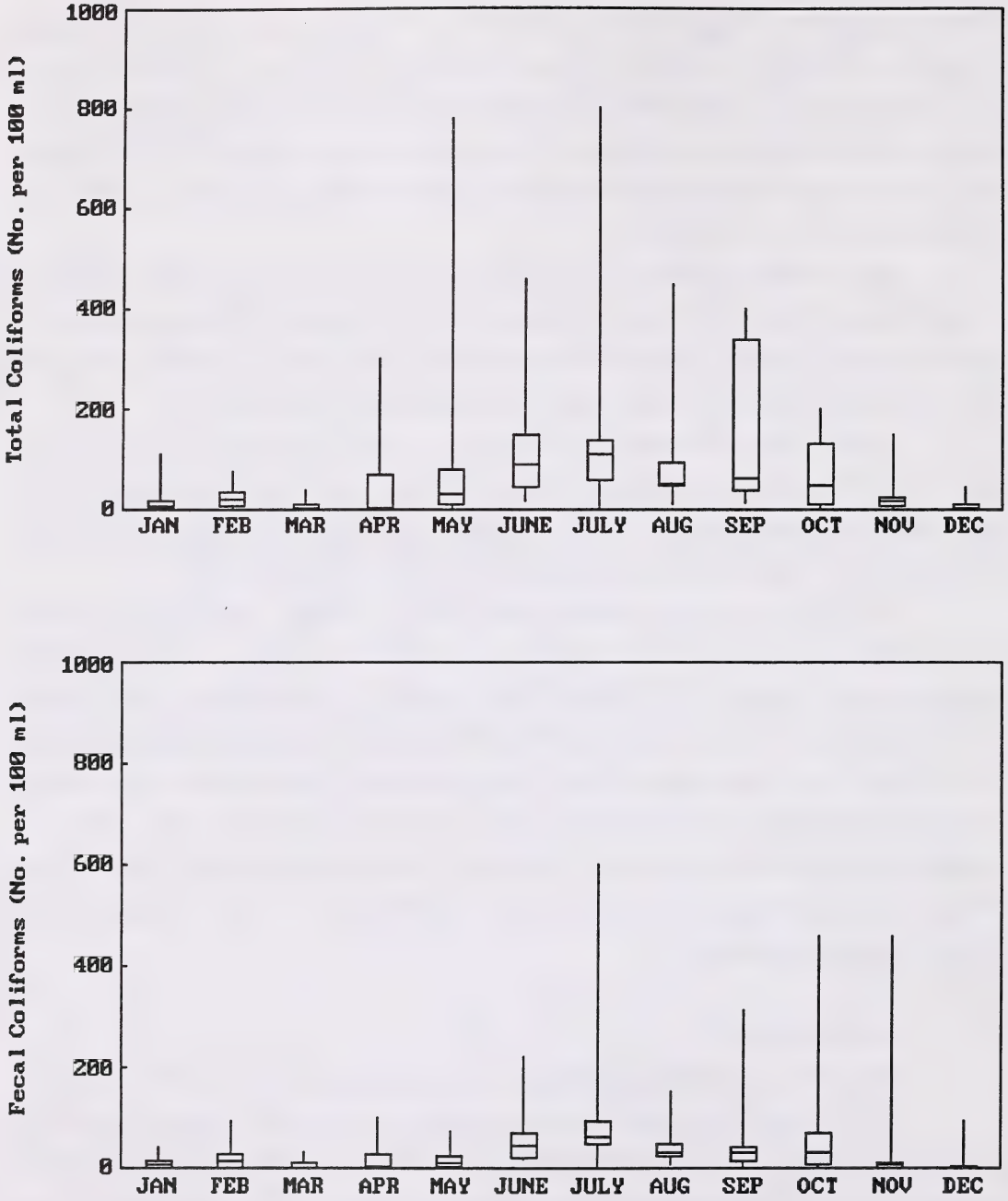


FIGURE 88. TOTAL AND FECAL COLIFORM COUNTS. SEASONAL CHANGES AT UNWIN (1974 - 1990).

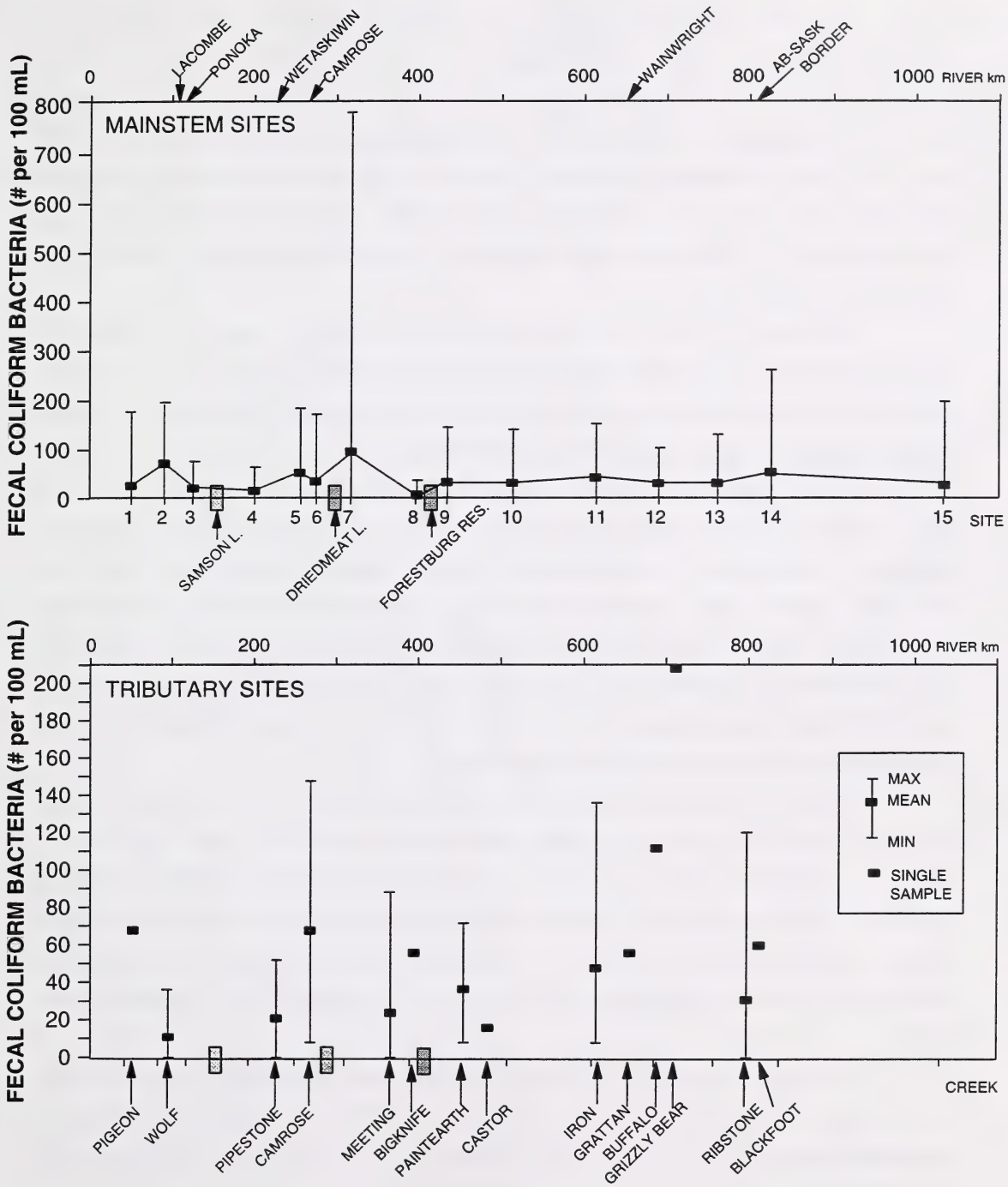


FIGURE 89. FECAL COLIFORM BACTERIA in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

Macrophytes and periphytic algae were not sampled in 1989-1990 surveys. However, large stands of macrophytes were observed at most sampling locations. Several *Potamogeton* species (i.e., *P. richardsonii, P. vaginatus, P. zosteriformis), Ceratophyllum*, and *Myriophyllum* were among the macrophytes growing at site 1 (Highway 611). *P. richardsonii* and *P. vaginatus* were most commonly seen at other sites. By mid-summer, filamentous green algae formed dense mats along the shoreline and in backwaters. Globulous blue-green algae (*Nostoc* spp.) were often associated with these filamentous green algae and they were also important on riffles downstream of the Forestburg Reservoir. Bryophytes were also growing on these riffles.

Chlorophyll *a*, the most common photosynthetic pigment in plants, is a measure of phytoplankton biomass. In 1989-1990, average phytoplankton chlorophyll *a* levels were especially high in the stretch downstream of Samson Lake and upstream of the Forestburg Reservoir (Figure 89). Although average concentrations ranged from 35 to 60 µg/L, values as high as 170 µg/L were recorded in that area. The very high levels which were generally recorded in summer (site 4, downstream Samson Lake) or in fall (site 7, downstream Driedmeat Lake) are indicative of the influence of these lakes on the river (Figure 90). Both lakes are hypereutrophic and are characterized by chronic algal blooms (Mitchell and Prepas 1990); their outflow contributes algae and nutrients downstream. At the same time, river flows are slowed down by the passage through the lakes and through macrophyte beds at or near the lake outlets. Consequently, ideal conditions for phytoplankton growth are extended to the river. Chlorophyll *a* levels in the eastern portion of the Battle River (downstream of site 9) were much less variable seasonally than in the western portion of the river and averages were approximately 20 µg/L.

Samples collected in early May 1989 are noteworthy because of their very high chlorophyll content at all sites, including those in the eastern portion of the basin (Figure 91). These high chlorophyll levels may be a result of several factors. Sampling occurred at a time when spring runoff had subsided and suspended solid levels were declining, but when increasing water temperatures and adequate nutrient levels created favourable conditions for algal growth. Inoculation by lake phytoplankton and by phytoplankton from municipal wastewater discharges (see section 4.2) could have increased river chlorophyll *a* levels even further.

In the long-term data set from Unwin, chlorophyll *a* also peaked in spring and a second, less important peak occurred in fall (Figure 91). The seasonal variability in the long-term data corresponds with the observations made in the lower portion of the basin in 1989-1990, but not with those for the upper portion of the basin.

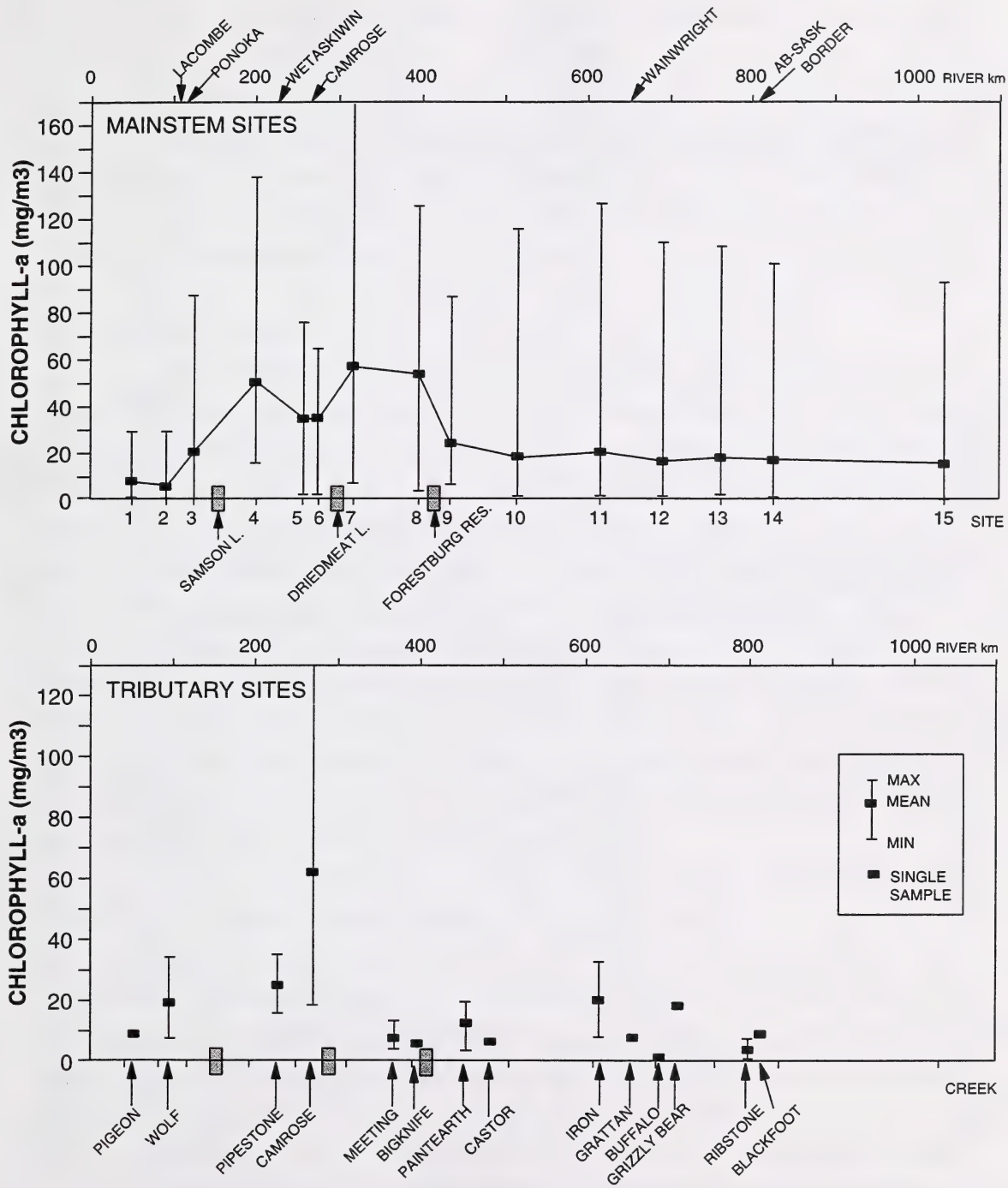


FIGURE 90. PHYTOPLANKTON CHLOROPHYLL-a in the Battle River (1989 and 1990 surveys) and its tributaries (1990 surveys).

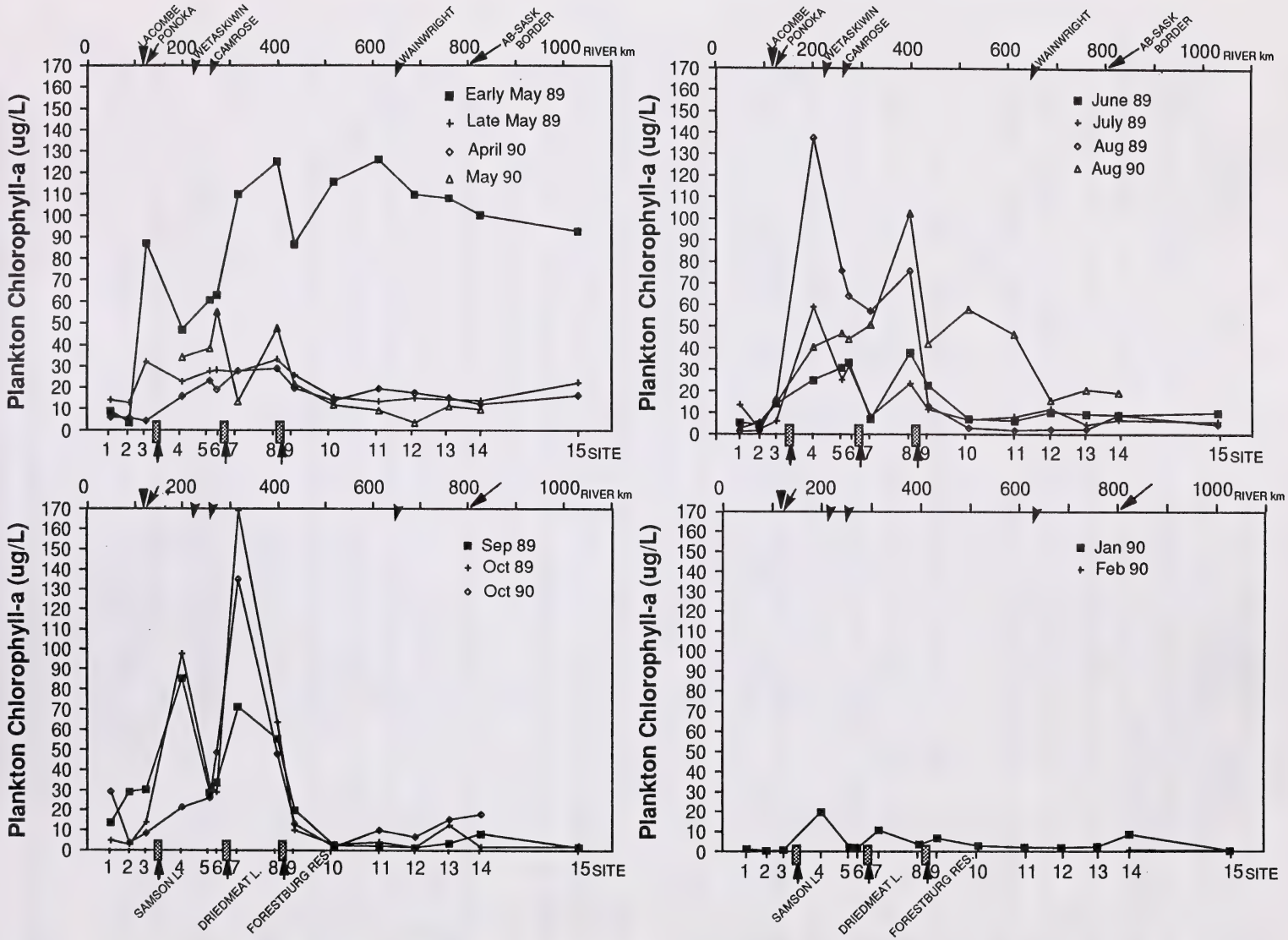


FIGURE 91. PLANKTON CHLOROPHYLL a - longitudinal changes recorded during seasonal surveys (1989 - 1990).

There are no AASWQIG, PPWBO or CWQG for phytoplankton chlorophyll *a* levels. Chlorophyll *a* levels in the Battle River between Samson Lake and the Forestburg Reservoir are much higher than those reported for other rivers in the province (Shaw et al. 1991, Sosiak 1990). According to the OECD (1982) trophic classification of lakes, which uses average summer phytoplankton chlorophyll *a* levels, that section of the Battle River is classified as hypereutrophic. However, average chlorophyll *a* levels in the lower portion of the river, which are similar to those measured in the North Saskatchewan River downstream of Edmonton, are typical of eutrophic waters.

4.3.7.3 Aquatic Invertebrates

Aquatic invertebrates are often very abundant and diverse in rivers. They swim in the water, live near the sediment-water interface, burrow in the sediments, and dwell among rocks or among aquatic vegetation. Because aquatic invertebrates process live or dead organic matter, they are key components in the transfer of energy along food chains. In this respect they are especially important as a food source for fish and many aquatic birds. Invertebrate groups exhibit differences in sensitivity to changes in water quality, and the results of the analyses of zoobenthos communities (i.e., those organisms that live in or near the river bed) have been used extensively in pollution ecology as indicators of water quality.

Zoobenthos has not been part of the long-term monitoring program at Unwin and aquatic invertebrate data for the Battle River basin are generally scarce. Although detailed studies were carried out on some aspects of dynamics in unionid (large clam) populations of localized areas (Andrews 1987) it was only in 1984 that aquatic invertebrates were surveyed over an extensive portion of the river as part of a fish habitat study (Fernet et al. 1985). The prime objective of that work was to evaluate the food base for fish, and no attempt was made to enumerate or identify invertebrates in detail.

The intent of the 1989 surveys was to identify longitudinal trends in the zoobenthos of the Battle River and to relate these to physical, chemical, or other biological trends.

Data from quantitative samples, collected with an Ekman dredge from the soft substrates in the center channel of the Battle River, were used to identify these trends (see section 2.1.4). Differences in taxonomic richness and in abundance of organisms between the center channel and the littoral zone were often so apparent that qualitative samples (dipnet sweeps) were collected from the littoral zone in order to obtain a more realistic picture of aquatic invertebrate diversity in the Battle River.

Benthic invertebrate data are summarized in Tables 20 to 23, Figure 92 to 96, and Appendix 4.

The invertebrate fauna from the center channel of the Battle River consisted primarily of Oligochaetes (bristle worms), Chironomidae (midges) and Nematoda (roundworms), but Unionidae and

Table 20. Percent contribution of major taxa to total numbers of invertebrates taken from mid-channel samples.

SITE	OLIGOCHAETA	NEMATODA	CHIRONOMIDAE	AMPHIPODA	BIVALVA	OTHER
Spring 1989						
1	42.8	12.7	18.9	7.3	8.4	9.8
2	41.2	10.5	8.9	6.4	27.0	6.0
3	60.5	0.9	2.4	26.0	6.9	3.3
4	17.2	7.5	50.3	0.1	0.7	24.3
5	70.6	0.6	3.0	0.1	7.7	18.1
6	26.6	45.5	14.9	2.0	0.3	10.8
7	61.0	9.3	14.8	3.4	0.9	10.6
8	38.2	17.6	13.2	7.1	1.4	22.5
9	38.6	1.1	8.4	27.8	17.0	7.0
10	6.0	1.5	8.2	12.7	4.5	67.2
11	3.4	1.3	82.6	0.1	1.0	11.6
12	34.9	3.7	15.1	11.4	16.8	18.2
13	58.9	3.5	9.5	17.2	0.4	10.5
14	17.9	1.8	14.3	13.4	2.7	50.0
15	13.1	1.6	7.7	17.3	9.6	50.6
Fall 1989						
1	15.5	1.3	18.2	12.1	50.3	2.6
2	0.2	0.1	83.0	5.5	0.1	11.1
3	24.7	0.5	48.6	20.0	2.9	3.4
4	-	-	-	-	-	-
5	37.5	1.2	47.0	11.8	0.7	1.8
6	52.7	26.9	15.9	3.1	0.1	1.1
7	59.6	2.1	1.0	16.0	1.7	19.5
8	-	-	-	-	-	-
9	23.8	1.7	41.6	13.9	4.9	14.1
10	1.5	0.2	90.6	0.6	0.4	6.7
11	49.9	1.4	29.8	0.8	0.0	18.1
12	11.5	0.1	57.0	19.1	0.3	12.1
13	2.7	0.6	63.4	23.1	0.1	10.1
14	3.0	0.0	47.0	6.1	15.2	28.8
15	7.8	0.0	85.9	3.4	0.2	2.6

- No samples

Table 21. Invertebrate taxa identified in the Battle River in 1989.

TAXON	MID-CHANNEL		SHORELINE	
	SPRING	FALL	VEGETATION	NO VEGETATION
Coelenterata				
Hydra	yes	yes	yes	yes
Nematoda	yes	yes	yes	yes
Oligochaeta				
Enchytraeidae	yes	yes	yes	yes
Naididae	yes	yes	yes	yes
Tubificidae	yes	yes	yes	yes
Hirudinea				
Glossiphoniidae	no	no	yes	no
Glossiphonia complanata	yes	yes	yes	yes
Helobdella	no	yes	yes	yes
Helobdella stagnalis	yes	yes	yes	yes
Theromyzon	no	yes	yes	no
Erpobdellidae	yes	yes	yes	yes
Nephelopsis obscura	no	no	yes	yes
Nephelopsis	yes	yes	no	no
Erpobdella punctata	yes	yes	no	yes
Crustacea				
Copepoda				
Calanoida	yes	no	yes	yes
Harpacticoida	no	yes	yes	no
Cyclopoida	yes	yes	yes	yes
Amphipoda				
Hyalella azteca	yes	yes	yes	yes
Gammarus lacustris	yes	yes	yes	yes
Ostracoda	yes	yes	yes	yes
Cladocera				
Ceriodaphnia	no	yes	yes	yes
Chydoridae	yes	no	no	no
Chydorus	no	yes	yes	yes
Ilyocryptus sordidus	no	yes	yes	yes
Macrothrix	no	yes	yes	yes
Graptoleberis testudinaria	no	no	yes	yes
Acroperus harpae	no	no	yes	no
Pleuroxus	no	yes	yes	yes
Alona rectangula	no	no	yes	no
Eurycercus lamellatus	no	no	yes	no
Leydigia	no	yes	yes	yes
Daphnia	yes	yes	no	no
Bosmina	yes	no	no	no
Ephemeroptera				
Hexagenia	no	yes	yes	yes
Baetidae	yes	yes	yes	yes
Baetis	no	no	yes	yes
Callibaetis	no	yes	yes	yes
Heptageniidae	no	yes	yes	no
Heptagenia	no	no	yes	yes
Stenonema	no	yes	yes	yes
Ephemerellidae	no	no	yes	no
Caenis	yes	yes	yes	yes
Tricorythodes	no	yes	yes	yes
Leptophlebiidae	no	yes	yes	no

TAXON	MID-CHANNEL		SHORELINE	
	SPRING	FALL	VEGETATION	NO VEGETATION
Paraleptophlebia	yes	no	yes	yes
Leptophlebia	no	yes	yes	yes
Trichoptera				
Hydropsychidae	no	yes	yes	no
Hydropsyche	no	yes	yes	no
Hydroptila	no	no	no	yes
Polycentropus	yes	yes	yes	yes
Ptilostomis	no	yes	yes	no
Oecetis	yes	yes	yes	yes
Ceraclea	yes	yes	yes	yes
Nectopsyche	no	yes	yes	no
Limnephilidae	no	no	yes	yes
Limnephilus	no	yes	yes	yes
Triaenodes	yes	yes	yes	no
Molanna	yes	yes	no	yes
Brachycentrus	no	yes	no	no
Neureclipsis	no	yes	no	no
Mystacides	no	yes	no	no
Nemotaulius	yes	yes	yes	no
Psychoglypha	yes	no	no	no
Plecoptera				
Perlodidae	no	yes	yes	yes
Isoperla	no	yes	yes	yes
Taeniopteryx	no	no	yes	no
Lepidoptera	yes	no	no	no
Collembola	no	yes	yes	no
Coleopotera				
Dytiscidae	no	yes	yes	yes
Acilius	no	no	yes	no
Elmidae	no	yes	yes	yes
Dubiraphia	yes	yes	yes	yes
Optioservus	no	yes	no	no
Chrysomelidae	yes	no	yes	no
Donacia	no	yes	yes	no
Gyrinis	no	no	yes	no
Haliplus	yes	yes	yes	no
Paracymus	no	no	yes	no
Narpus	yes	no	no	no
Hemiptera				
Corixidae	no	yes	yes	yes
Corisella	no	yes	yes	yes
Cymatia americana	no	no	yes	no
Notonecta	no	no	yes	yes
Mesovelia	no	no	yes	no
Megaloptera				
Sialis	no	yes	no	no
Odonata				
Enallagma	yes	yes	yes	yes
Aeshna	no	no	yes	no
Gomphus	no	yes	yes	no
Ophiogomphus	no	yes	no	no
Somatochlora	no	yes	no	no
Cordulia	yes	no	no	no
Diptera				

TAXON	MID-CHANNEL		SHORELINE	
	SPRING	FALL	VEGETATION	NO VEGETATION
Chironomidae				
Chironomini	yes	yes	yes	yes
Tanytarsini	yes	yes	yes	yes
Diamesinae	no	yes	yes	yes
Ceratopogonidae	yes	yes	yes	yes
Chaoborus	yes	yes	no	no
Tipulidae	no	yes	no	yes
Chrysops	yes	yes	yes	yes
Simulium	yes	yes	yes	yes
Dixella	no	no	yes	no
Pericoma	no	no	yes	no
Stratiomyidae	no	no	no	yes
Prionocera	no	no	yes	no
Tabanus	yes	no	no	no
Acari	yes	yes	yes	yes
Mollusca				
Gastropoda	yes	yes		
Planorbula	yes	no	yes	no
Helisoma	no	no	yes	no
Pulmonata	no	no	no	yes
Physa	no	yes	yes	yes
Lymnaea	yes	yes	yes	yes
Promenetus	yes	yes	yes	no
Armiger	no	no	yes	no
Valvata	yes	yes	yes	yes
Pelecypoda				
Sphearriidae	yes	yes	yes	yes
Sphaerium	yes	yes	yes	yes
Pisidium	yes	yes	yes	yes
Anodontinae	yes	yes	no	no
Thysanoptera	no	no	yes	yes

Table 22. Comparison of number of taxa collected during mid-channel and shoreline sampling in the Battle River in 1989.

SITE	DIPNET SWEEPS		EKMAN DREDGE CENTRE CHANNEL
	VEGETATION	NO VEGETATION	
1	48	-	18
2	28	37	24
3	31	24	20
4	-	-	-
5	35	23	10
6	28	29	12
7	50	32	25
8	-	-	-
9	22	28	17
10	43	33	24
11	-	-	-
12	34	28	20
13	37	22	12
14	37	25	4
15	49	28	14

- No sample taken

Table 23. Percent contribution of major taxa in dipnet sweeps.

SITE	CHIRONOMIDAE		OLIGOCHAETA		AMPHIPODA		COPEPODA		CLADOCERA		OTHER	
	P*	A*	P	A	P	A	P	A	P	A	P	A
1	7*	-	0	0	7	-	39	-	39	-	8	-
2	65	41	0	0	0	6	27	27	1	1	10	25
3	15	19	0	1	8	7	73	62	0	1	4	10
4	-	-	-	-	-	-	-	-	-	-	-	-
5	21	29	11	6	2	4	59	31	0	2	7	28
6	4	18	6	14	6	13	59	11	15	0	10	44
7	1	0	1	8	13	10	58	53	22	19	5	10
8	-	-	-	-	-	-	-	-	-	-	-	-
9	0	0	0	0	6	3	92	96	0	0	2	1
10	7	9	0	11	0	0	36	66	52	3	5	11
11	-	-	-	-	-	-	-	-	-	-	-	-
12	1	8	0	2	0	0	67	88	28	0	4	2
13	35	48	5	9	0	1	51	35	3	0	6	7
14	2	13	2	4	6	0	83	37	0	3	7	43
15	10	3	12	17	14	3	25	60	0	0	39	17

P* Sweeps taken where macrophytes were present
A* Sweeps in areas devoid of macrophytes
* All values calculated in percentage
- No samples taken

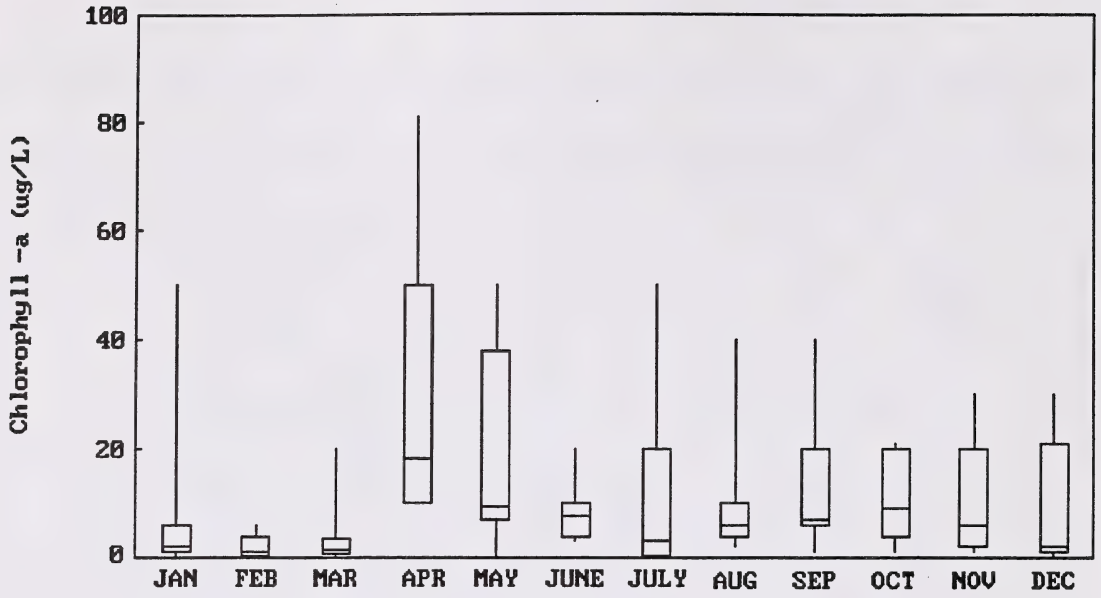


FIGURE 92. PLANKTON CHLOROPHYLL-A SEASONAL CHANGES AT UNWIN (1980 - 1990).

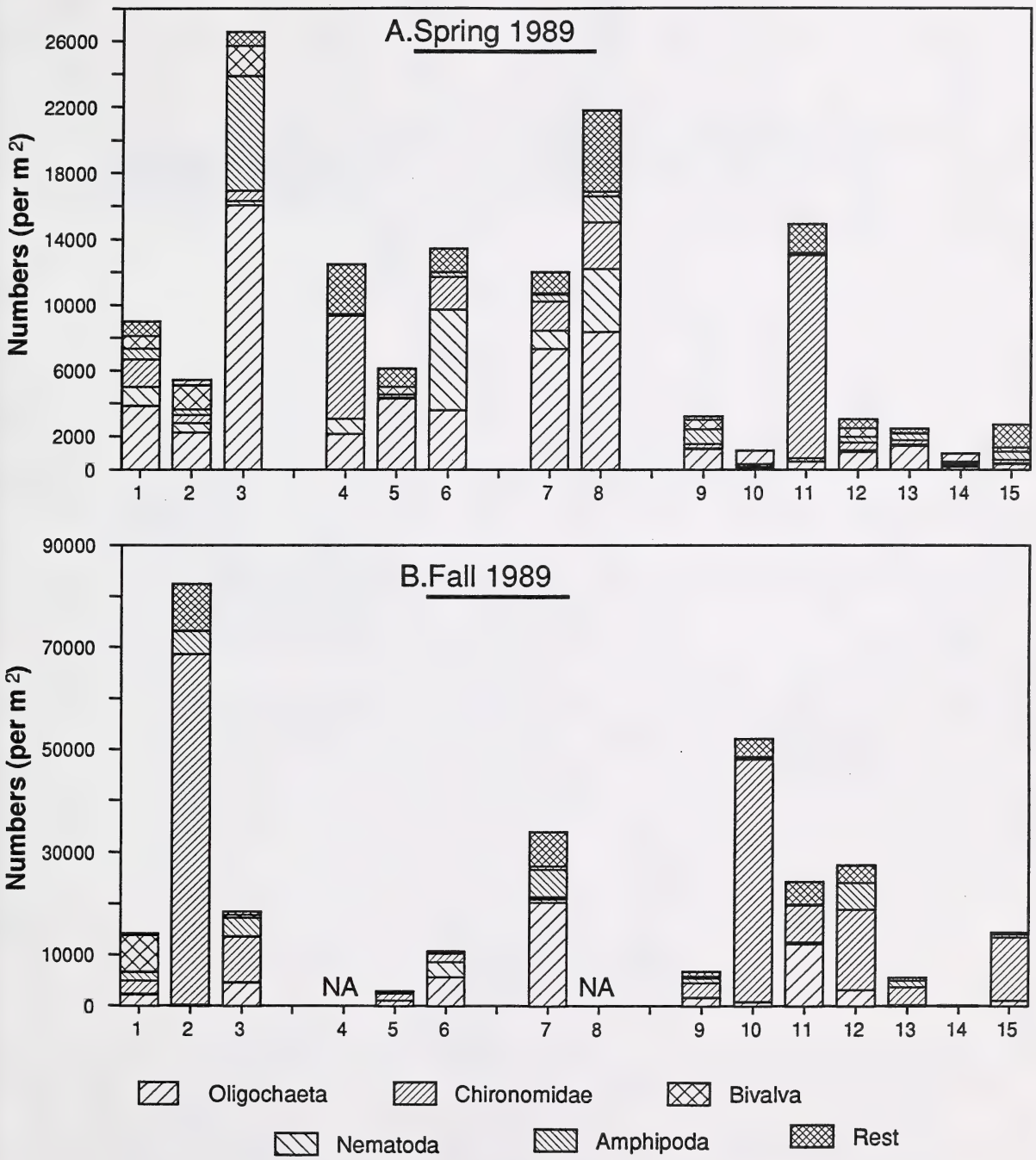


FIGURE 93. Mean density of invertebrates collected during mid-channel sampling in the Battle River in 1989.

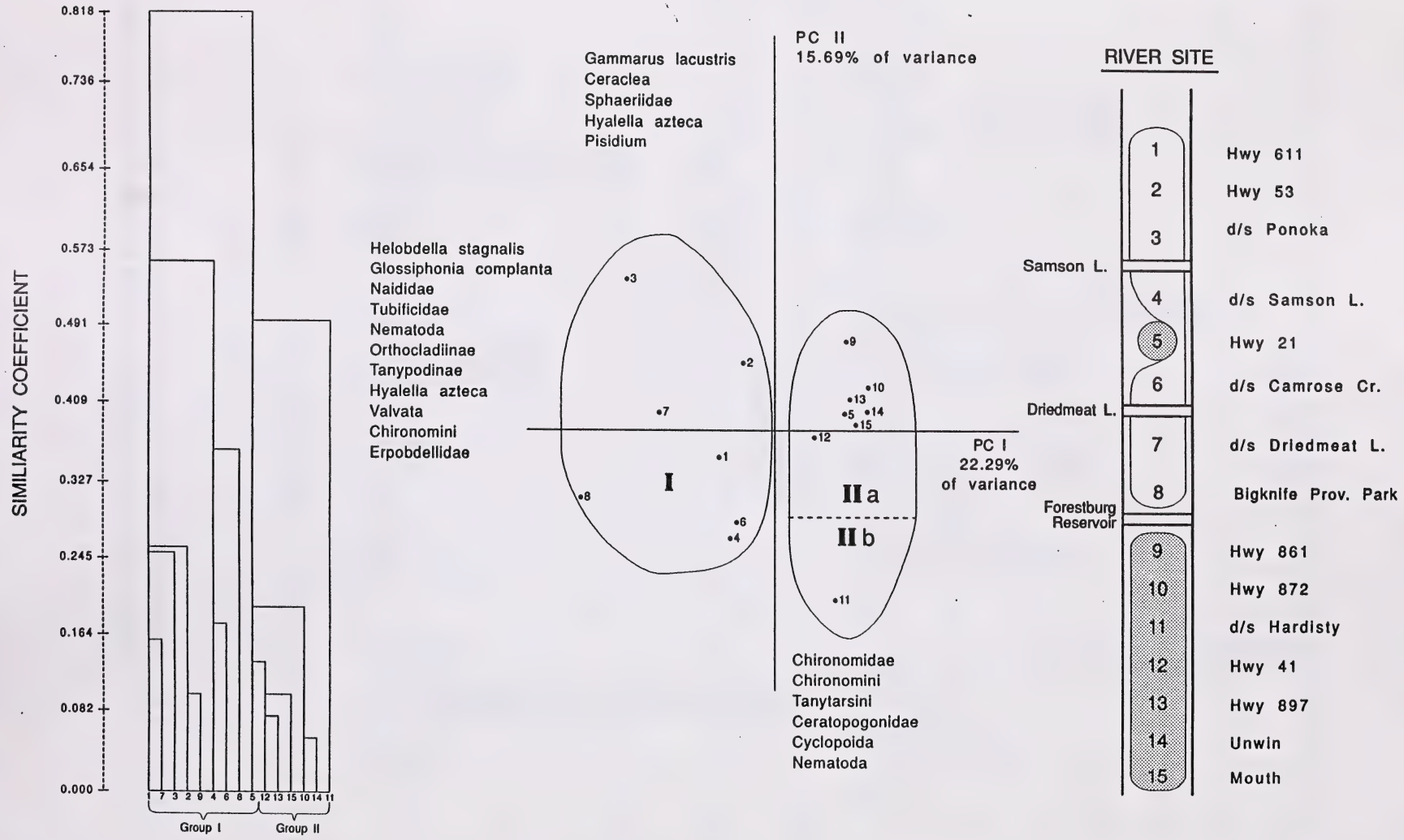


FIGURE 94a. RESULTS OF MULTIVARIATE ANALYSES OF INVERTEBRATE DATA FROM THE BATTLE RIVER (Mid-Channel) SPRING 1989.

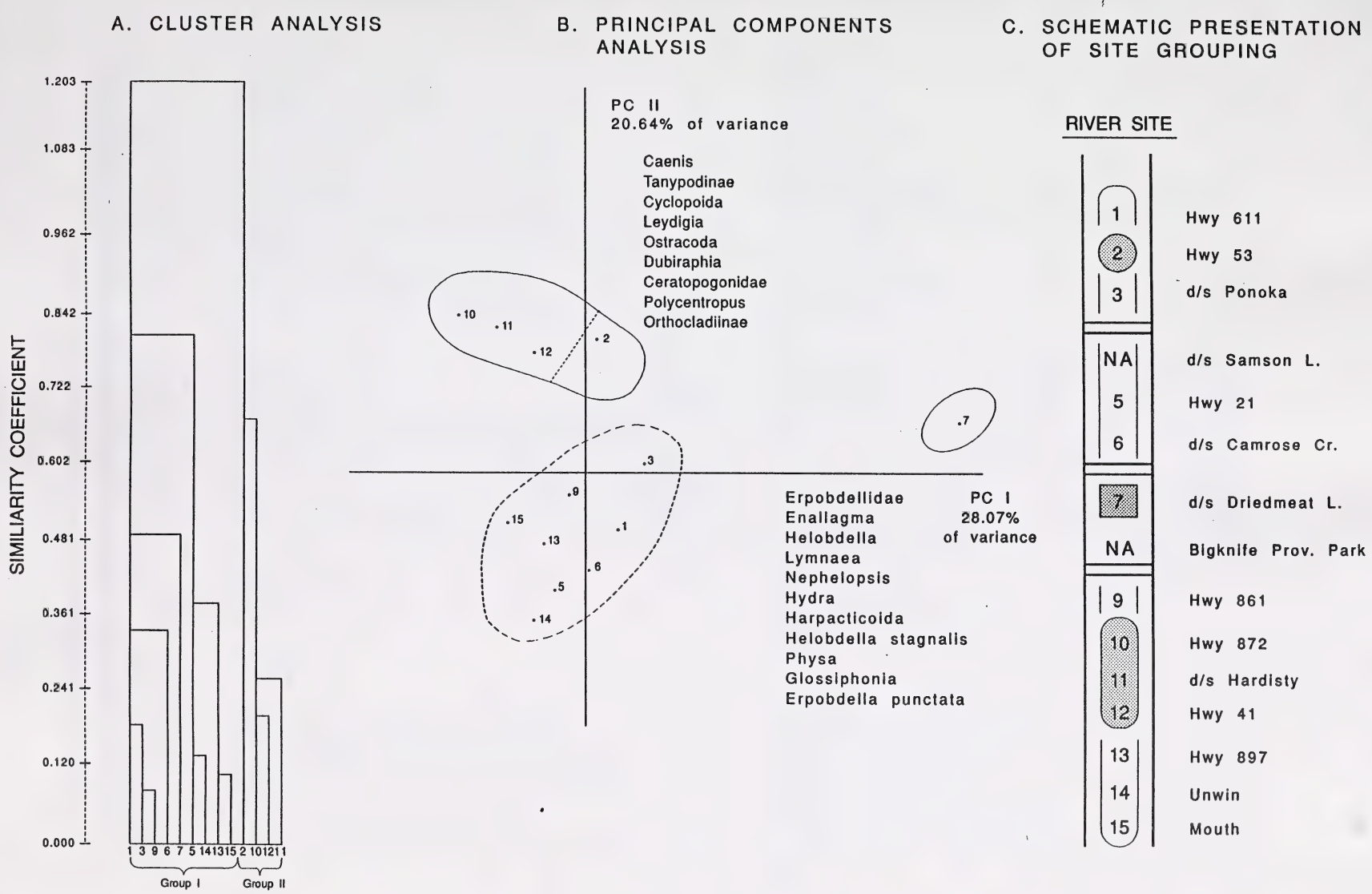


FIGURE 94b. RESULTS OF MULTIVARIATE ANALYSES OF INVERTEBRATE DATA FROM THE BATTLE RIVER (Mid-Channel) FALL 1989.

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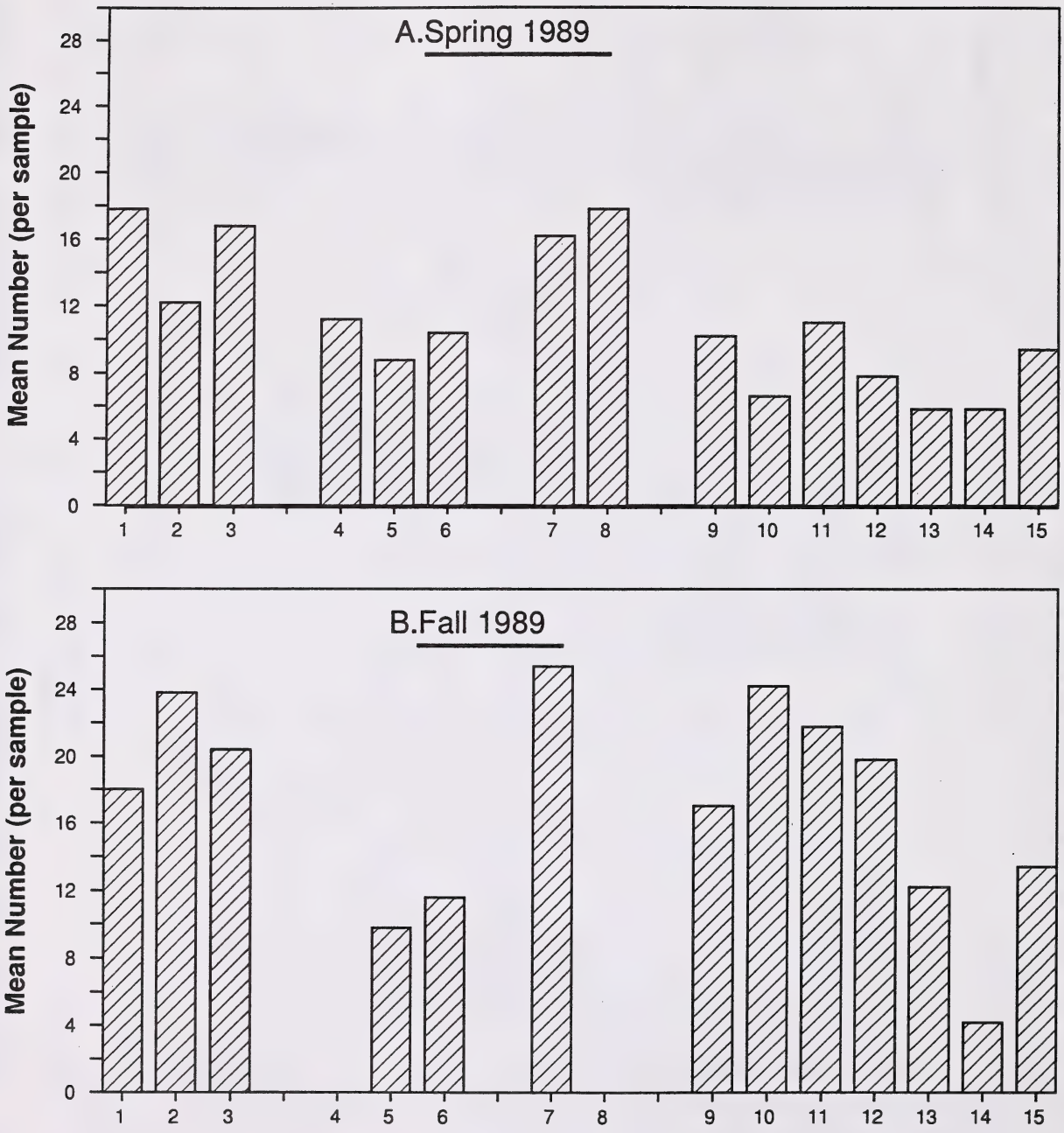

FIGURE 95. Mean number of invertebrate taxa collected at sites in the centre channel of the Battle River in 1989.

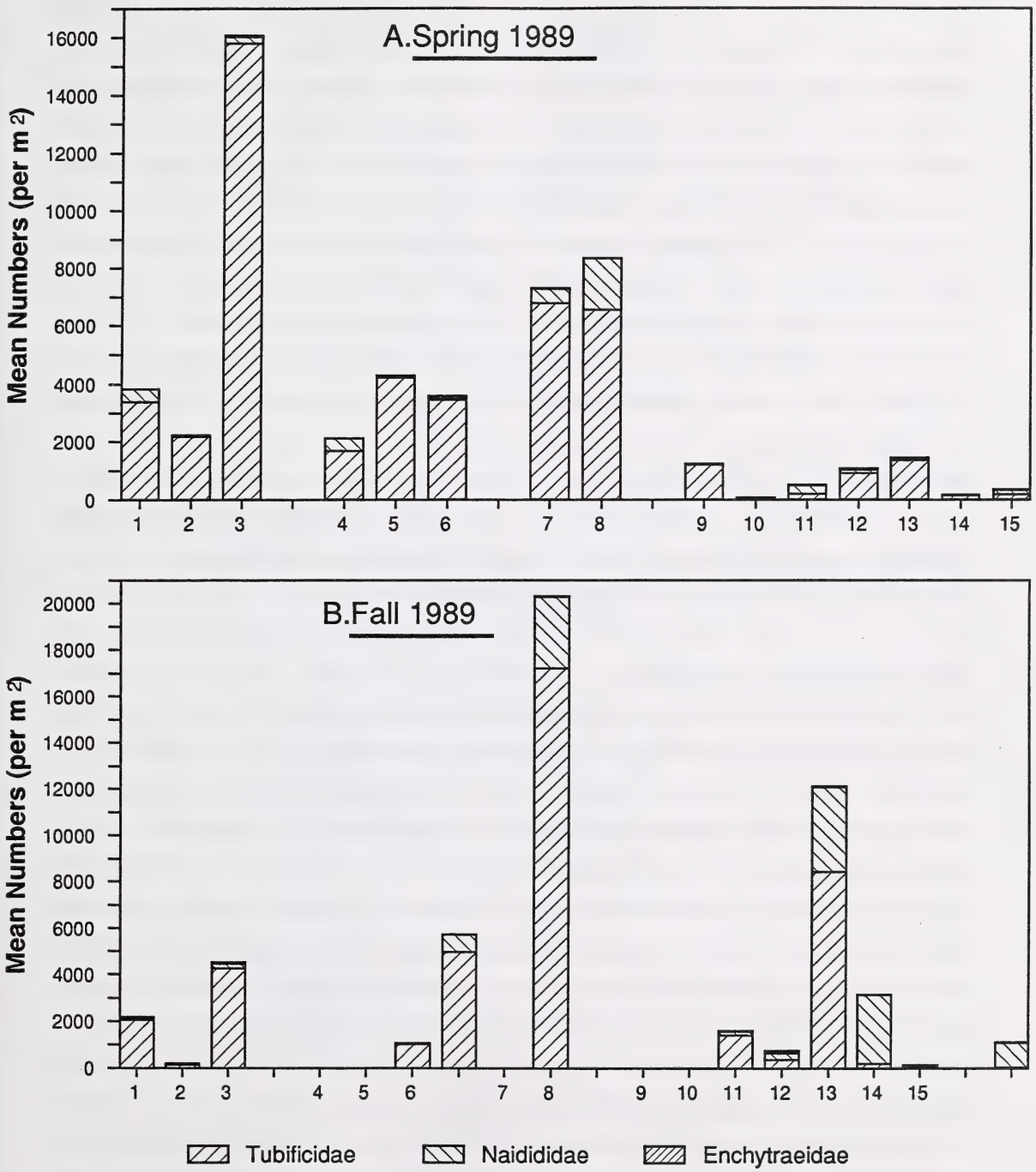

FIGURE 96. Mean number of Oligochaeta at sites in the centre channel of the Battle River in 1989.

Sphaeriidae (clams), Hirudinea (leeches), Amphipoda (scuds) and other Crustacea were often locally abundant (Figure 93, Table 20). This faunal composition is typical of large, sluggish rivers with soft substrates as described by Hynes (1972). It is quite different from the fauna of erosional habitats which typify the swift, well oxygenated waters of many other rivers of Alberta (Anderson 1992, Shaw et al. 1989 and 1992). In many ways, the invertebrate fauna of the Battle River is more like that of lentic than lotic environments. Many of the worms, midges and clams of the Battle River fauna are also common inhabitants of lakes and representatives of other taxa which belong to groups that are usually considered riverine are adapted to the slow moving or standing waters of the Battle River. For example, many of the mayflies and caddisflies (e.g., Ephemeroptera: *Hexagenia*, *Caenis*, *Tricorythodes*; Trichoptera: *Polycentropus*, *Hydroptila*, *Oecetis*, *Ceraclea*, *Nemotaulius*, *Psychoglypha*) (Table 21) which were encountered along the shoreline and occasionally in the main channel are often typical of both depositional areas of lotic environments and littoral areas of lentic environments (Merritt and Cummins 1984). The sluggish flow of the river allows the persistence of large populations of crustaceans, such as copepoda, ostracods, and cladocerans, especially among the macrophytes close to the shore. Beaver dams in some areas of the river create near stagnant conditions which also favour these small crustaceans, a situation not unlike that reported for the Bigoray River by Clifford (1978).

Influence of Substrate Characteristics

Substrate characteristics are important determinants of zoobenthos composition (e.g., Hynes 1972, Minshall 1984), even in a river such as the Battle River where slow flows ultimately reduce substrate heterogeneity. Some of the longitudinal trends which were observed in the zoobenthos during the spring survey were related to the transition from fine, organically rich mud, typical of the upper reaches (sites 1 to 9), to the clean sands typical of the lower reaches (site 10 to 15). Two sites were atypical of their reaches; site 5 (Highway 21) had a sandy substrate, and site 11 (downstream Hardisty) had rich, organic mud. Spring samples collected from rich organic muds contained larger numbers of invertebrates than samples from sandy substrates (Figure 93a). Sandy substrates generally have lower invertebrate densities than muddy or rocky substrates (e.g., Minshall 1984, Shaw et al. 1989). Sand is a rather inhospitable type of substrate for invertebrates. It offers a low diversity of habitats and, because of its shifting nature, burrows tend to collapse causing organisms which live near the surface to be swept away by currents.

In the Battle River, the differences in substrate types affected spring densities of individual taxonomic groups (Figure 93a, Appendix 4) and accounted for the differentiation of two faunal associations by multivariate analysis techniques (Figure 94a). Sites on rich organic muds were typified by

larger numbers of *Helobdella stagnalis, Glossiphonia complanata*, Naididae, Tubificidae, Nematoda, Chironomini, Orthcladiinae, Tanypodinae, *Hyalella azteca, Valvata* and Erpobdellidae than sites on sandy substrates (Figure 94a). As expected, the fauna from site 5 (Highway 21) was comparable to that of sandy substrates further downstream. Rather unexpectedly, so was the fauna from site 11. Even though the rich organic muds from site 11 harbored more midges (Chironomidae, Chironomini, Tanytarsini), Ceratopogonidae, Cyclopoida, and Nematoda than the sandy sites which had somewhat larger numbers of *Gammarus lacustris, Hyalella azteca, Ceraclea*, Sphaeriidae and *Pisidium*.

The data in Figures 93b, and 94b indicate that substrate was less important in defining longitudinal patterns or faunal associations in the fall and that other factors discussed below had an overriding effect. However, it is probable that the low flows in summer and fall stabilized the sands from site 9 to site 15, allowing for the development of much larger populations than during the high flows in spring.

Influence of Municipal Discharges

Riverine aquatic invertebrates are particularly sensitive to the discharge of municipal wastewater. Such discharges represent a source of food for aquatic organisms which typically respond by large increases in numbers downstream of the outfall as long as dissolved oxygen or toxicity are not limiting (e.g., Hynes 1960, Anderson 1986, Anderson 1992). In rivers where dissolved oxygen levels are limiting, community composition may change drastically as worms (mainly Tubificidae) and midges (mainly Chironomidae) become increasingly dominant and as less tolerant groups decline (e.g., Hynes 1960, Aston 1973, Brinkhurst 1965, 1966, 1972).

Most of the municipal discharges to the Battle River occur between site 2 (Highway 53) and site 6 (downstream Camrose Creek). In spring, all of these sites, except site 5 for reasons discussed earlier, had somewhat higher invertebrate numbers than site 1 (Highway 611) and site 2 (Highway 53) which are not influenced by municipal discharges (Figure 93). However, there was no consistent evidence of a reduction in species diversity (Figure 95a) and the increase in total numbers or number of tubificid worms (Figure 96a) and chironomid larvae (Figure 97a) was slight compared to those documented in cases of gross organic pollution (e.g., Brinkhurst 1965). In this regard it is notable that frequently cited "textbook" examples describe invertebrate responses to organic enrichment from continuous discharges of often poorly treated effluent. There are very few studies that deal with the effects of intermittent discharges of effluents which have a fairly high quality. Using in-stream pulse experiments Edwards et al. (1991) showed that short-term increases in ammonia levels induced mortality in caged fish and increased drift rates of aquatic

FIGURE 97. Mean number of Chironomidae at sites in the centre channel of the Battle River in 1989.

invertebrates. Because ammonia levels are occasionally high in the Battle River following the discharge of effluent (sections 4.2 and 4.3.4.1) similar behavioral responses could be expected in the Battle River. However, it is likely that indirect (chronic) effects rather than direct (acute) effects have more influence on aquatic invertebrates. Among the indirect effects are the enhancement of primary producer standing stocks (section 4.3.7.2) which contribute to heightened fluctuations of both diurnal and seasonal dissolved oxygen (section 4.3.3), particularly in the upper reaches (sites 3 to 8). In their pulse experiments, Edwards et al. (1991) also showed that short periods of low dissolved oxygen levels increased the drift rates of all but the most tolerant taxa. In the Battle River, such events would enhance the dominance of Tubificidae and Chironomidae which can withstand rather long periods of anoxia (e.g., Berg et al. 1962, Palmer 1968). The low population density and diversity observed at site 6 (downstream Camrose Creek) in fall 1989 is indicative of the importance of such secondary effects (Figure 93b, 95b).

Influence of Macrophytes

Macrophytes are another factor which can affect zoobenthic distribution (Gregg and Rose 1985). Macrophytes increase both size and diversity of colonizable habitat (Minshall 1984), offer a greater abundance and diversity of food and provide refuge from swift water and large predators.

In the Battle River, the presence of macrophytes had a substantial influence on invertebrate diversity. Samples taken from the center of the channel had fewer species than samples taken along the shoreline, but samples taken from shorelines where no macrophytes were growing, had a lower diversity than samples taken from shorelines with macrophyte beds (Table 22). As a result of habitat preferences, many taxonomic groups were only encountered among macrophytes or in the center of the channel (Table 21). In contrast with the fauna from fine-grained, macrophyte-free substrates in the center of the river, the fauna from macrophyte beds contained an abundance and diversity of small crustaceans (Cyclopoida, Harpacticoida, Ostracoda, and especially Cladocera) (Table 23). Although many of these crustaceans are planktonic some such as *Ilyocryptus sordidus, Leydigia* spp., some copepoda, and many ostracods are truly benthic in habit. A large variety of insect larvae lived among the macrophytes (e.g., Ephemeroptera, Trichoptera, Coleoptera, Hemiptera, Odonata and Ostracoda). Many of these such as the ephemeropterans *Callibaetis* and *Baetis* or the trichopteran *Ptilostomus, Nectopsyche, Triaenodes, Brachycentrus, Neureclipsis* or *Mystacides*, often occur among vascular hydrophytes (Merritt and Cummins 1984). Other groups often encountered in large numbers among macrophytes included Mollusca (Gastropoda and Sphaeriidae), Amphipoda, and a fairly large number of Hirudinea species (Table 21).

Although macrophytes can have a positive influence on the composition of aquatic invertebrate communities, an over-abundance of macrophytes can create conditions which become limiting. Diurnal dissolved oxygen fluctuations in dense macrophyte beds can be severe (Cross et al. 1986). In areas where flow velocities are very low, anoxic conditions can persist near the sediments. Such extremes in dissolved oxygen levels can be particularly limiting to sensitive taxa.

The abundance of macrophytes at some sites in the Battle River during the summer months, and the rather sensitive balance between their positive and negative effects on the zoobenthos, likely contributed to the rather erratic longitudinal changes in numbers and species composition observed in fall of 1989 (Figure 93b to 97b).

Another factor which interfered with fall sampling and probably contributed to difficulties in recognizing longitudinal trends was the somewhat longer growing season for macrophytes in the upper portion of the basin. Macrophytes were still present in large numbers at some, but not all sites during the October sampling.

5.0 GENERAL DISCUSSION

As a result of climatic and geographic changes in their drainage basin, natural streams typically exhibit gradients in their physical and chemical characteristics (e.g., Hynes 1972, Whitton 1975). Noting that biological communities continuously adjust to these longitudinal habitat changes, Vannote et al. (1980) conceptualized the stream environment as a functional and structural continuum where up-stream conditions influence the downstream environment.

Although the Battle River exhibits some typical gradients along its course, the river also has features which lend it unique and complex limnological characteristics quite unlike those of most other rivers of the province. Among these are distinctive hydrological features and some aspects of human activities in the basin.

Hydrological Features

Unlike many other rivers in Alberta, the Battle River is not fed by mountain snowmelt. River discharge is controlled by local runoff resulting from snowmelt or heavy rains and by groundwater inputs. Most of the material transport in the river occurs during short periods of increased river discharge in spring and summer. Travel time in the river is very slow because of the shallow stream gradient and the presence of lakes such as Samson and Driedmeat lakes and the Forestburg Reservoir on the river. These lakes dampen changes in river flows and also influence downstream transport of materials. Depending on

seasonal changes in lake water quality and river discharge which influence flushing rates, lakes can act as traps or sources of materials. As river water passes through these water bodies, its quality is altered by natural processes typical of lake environments. The quality of the outflowing water exhibits characteristics and seasonal changes which are typical of shallow, eutrophic, lentic environments. The alternation of lotic and lentic sections in the upper Battle River effectively "resets" limnological features of the river and results in a departure from the river continuum concept.

Human Activities in the Basin

Several types of human activity are contributing to the unique water quality characteristics of the Battle River.

As the largest single user of water and the largest point source to the Battle River, Alberta Power Ltd. is responsible for the increase in river water temperatures for some distance below the Forestburg Reservoir at spring runoff. However, in winter when most of the river is ice- covered, the open water maintained in the Forestburg Reservoir acts as a major zone of re-aeration. The presence of DO in the river downstream of the reservoir is beneficial to aquatic life and some aspects of water quality (oxidized forms of mineral nitrogen prevail and dissolved concentrations of some metals such as iron and manganese are lower).

High nutrient loading is one of the leading causes of water quality problems in the Battle River. Although a large portion of this nutrient load can be attributed to human activity, natural causes are also involved. In absence of human activity, the trophic responses of water bodies are determined by the natural fertility of soils in the drainage basin which in turn depends on the geology and the climate of the area (OECD 1982). Considering that the Battle River flows through some of the most fertile soils of Alberta, and considering the river's size, gradient and hydrological features, the Battle River would be a fertile stream, even in the absence of human activity. Cultural eutrophication (i.e., contribution of nutrients to surface waters through human activities) can considerably accelerate the natural processes of eutrophication (e.g., Rohlich 1969). Nutrients can enter a stream via point (PS) or non-point sources (NPS).

Municipal discharges are the most conspicuous point sources of nutrients to the Battle River and its tributaries. Because of their number, their concentration pattern in the basin and the large volumes discharged relative to that of the river, municipal wastewater discharges have measurable effects on the river's water quality. These effects are both direct and indirect.

Direct effects, those which can be measured during the passage of an effluent plume, include increases in major ions and nutrients, especially phosphorus and ammonia. Ammonia levels in municipal effluents discharged to the Battle River are sometimes so high that in-stream concentrations over some distance downstream of the outfall exceed safe levels for aquatic life. The quality of municipal effluents treated in lagoons varies seasonally and tends to be better in fall than in spring (Beier 1987). However, aside from a lower incidence of elevated ammonia levels, in-stream concentrations of nutrients and major ions were similar during spring and fall because the dilution capacity of the river was lower in fall.

Indirect effects of municipal wastewater discharges are biological responses to increased nutrient levels in the river. Chain reactions, characteristic of nutrient enrichment of freshwaters (e.g., Hynes 1960, Rohlich 1969, OECD 1982), are encountered in the Battle River. Typically, increased nutrient levels stimulate primary production. The production of more plant biomass stimulates overall production along the foodweb. This results in wider fluctuations in diurnal and seasonal dissolved oxygen levels as photosynthesis increases the production of DO, but respiration and decomposition of larger amounts of organic matter increase its consumption. Patterns of some chemical processes such as redox reactions which influence the solubility of some compounds may be altered as a result. The composition of aquatic invertebrates and fish may shift in favour of species which are more tolerant of such fluctuations (e.g., Hynes 1972).

Sluggish flows which prevail in the Battle River and its tributaries extend the duration of impacts from municipal wastewater discharges on river water quality. Because material transport is very slow, nutrients are more readily immobilized in biomass or river and lake sediments. Travel time may therefore give a misleading indication of nutrient transport in the stream.

Surface runoff is the most conspicuous diffuse source of material to the Battle River. Runoff from agricultural land is a human contributor of nutrients to streams, but clearing of forested land is also known to accelerate the nutrient flow to surface waters. The diversity of geological and hydrological characteristics and the diversity of land uses make it very difficult to quantify contributions from non-point sources, especially on a basin wide scale. The quantitative evaluation of NPS contributions of materials would require much more detailed and intensive work than could be justified in a general water quality overview. Only an initial attempt was made in this report at estimating NPS contributions of selected 'conservative' elements. Although very preliminary in nature, the estimate provides some idea about the relative magnitude of NPS versus PS contributions and about their degree of year-to-year variability. The initial figures for phosphorus suggest that on average annual total municipal loads account for a higher proportion (68%) of the average annual in-stream load than NPS (32%). This initial estimate of NPS

contributions includes contributions from all sources including natural erosion and weathering and man-made sources such as agricultural land use and deforestation. Large year-to-year fluctuations in in-stream annual TP load are related to annual discharge fluctuations which in turn are related to fluctuations in annual precipitation. Although more surface runoff will occur in a wet year than a dry one, not all the in-stream load can be attributed to NPS contributions because transport of nutrients previously immobilized in biomass or stream and lake sediments would also be higher in a wet year. These initial estimates also suggest that in the Battle River, mass balancing of nutrient loads between two sites would not necessarily provide an accurate estimate of NPS contributions because transported nutrients may originate from various sources (i.e., NPS, PS, river sediments, biota).

Management Implications

In situations where human activities contribute a large amount of nutrients to surface waters, enhanced land and waste management practices may reduce the flow of nutrients and ultimately result in improved water quality. The reduction of nutrient loads from municipal discharges and the implementation of best management practices in agriculture would have beneficial effects on the water quality of the Battle River. However, as stated explicitly by OECD (1982) there is time lag between the implementation of nutrient reduction and responses from the water body; the duration of that time lag is difficult to predict. Response to management practices aimed at reducing man-made point- and non-point sources of nutrients would be delayed in the Battle River because on-stream lakes and the river itself act as a nutrient reservoir and because of the river's natural hydrology. Although a reduction of point-sources and the implementation of best management practices would eventually result in an enhancement of water quality, the natural state of the Battle River is such that the river would remain fairly productive.

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Appendix 1. Water quality data from 1989-1990 surveys

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE	DISCH.	TEMP.	PH	ALK TOT	HARD. TOT	SPEC. COND.	TDS	Ca	Mg	Na	K	HCO3	CO3	Cl	SO4	F	Si	DO
		D/M/Y	M3/S	DEG.C		mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
			97160S	02061F	10301F	10101L	10605L	02041L	00205L	20107L	12105L	11103L	19103L	06202L	06302L	17203L	16306L	09107L	14107L	08101L
PIGEON L. CREEK	00AL05FA0225	03-Apr-90	2.09	2.3	9															
EAST OF HWY 611		22-May-90	1.58	8.4		161	132	319	173	33	12	17	5	196		2.1	7	0.11	10.5	
		28-Aug-90	2.13	15.2	8.6															
		09-Oct-90	0.862	6.3	8.4															
BATTLE RIVER (SITE 1)	00AL05FA0250	02-May-89	1.88	4.6	7.8	137	108	278	150	28	9	16	3.3	167		2.2	9	0.08	1.7	
AT HWY 611		30-May-89	2.59	11.2	8	180	144	356	196	38	12	22	3.1	219		2.8	10	0.1	0.5	
		26-Jun-89	0.624	16.9	7.7	199	149	387	212	40	12	25	2.9	243		2.2	10	0.11	2	
		25-Jul-89	0.672	18.4	7	192	143	372	203	36	13	26	2.6	234		2.5	8	0.11	2.4	4.9
		23-Aug-89	0.804	17	7.4	198	142	385	209	37	12	27	2.9	241		2.9	8	0.1	4.7	
		27-Sep-89	0.47	12.1	6.9	193	142	382	215	37	12	27	3.3	235		2.5	16	0.11	4.2	
		24-Oct-89	0.565	3.7	8.5	215	160	416	230	41	14	29	3	262		2.3	10	0.11	2	
		09-Jan-90		0.2	7.7	212	162	416	230	40	15	30	3.4	258		2.1	11	0.11	2.7	5.35
		07-Feb-90		0.3	7.9	224	166	439	244	40	16	35	3.2	273		2.2	12	0.12	2.8	2.91
		03-Apr-90	8.58	0.4	8.7	121	102	251	134	26	9	10	6.2	148		2.4	7	0.07	4	9.81
		22-May-90	3.68	9.4	7.8	198	158	386	214	42	13	26	3.2	241		1.9	9	0.1	2.7	
		28-Aug-90	2.68	14.4	8	187	151	368	200	39	13	22	2.9	228		2.1	8	0.1	2.2	9.25
		09-Oct-90	1.23	5.8	8.2	246	192	477	269	49	17	35	3.5	300		2.5	14	0.13	0.5	10.49
BATTLE RIVER (SITE 2)	00AL05FA0280	02-May-89	3.207	10.1	7.6	168	139	353	198	36	12	20	6.3	205		3.4	19	0.1	4	
AT HWY 53, U/S PONOKA		30-May-89	3.765	12.3	7.9	202	169	413	229	43	15	25	4	246		4	17	0.11	3	
		26-Jun-89	0.646	18.1	8.3	239	178	458	258	45	16	35	3.3	274	8	3	12	0.14	0.6	
		25-Jul-89	0.797	19.8	8.4	233	175	428	249	42	17	33	3.6	256	14	4	10	0.14	0.5	
		23-Aug-89	1.21	18.2	7.9	229	163	438	243	39	16	35	3.6	265	7	2.2	10	0.11	2.1	8.27
		27-Sep-89	0.463	12.4	7.9	233	171	444	248	42	16	34	3.8	280	2	2.8	10	0.12	0.3	
		24-Oct-89	0.946	4.3	8.5	259	191	506	286	47	18	40	3.9	316		2.9	18	0.12	2.1	
		09-Jan-90		0	7.6	290	220	564	315	52	22	43	4.5	354		2.2	16	0.13	7.5	
		06-Feb-90		0.3	7.9	318	232	602	342	55	23	49	3.8	388		2.6	17	0.14	8	
		03-Apr-90	19.3	4.2	8.2	113	102	251	133	26	9	7	9.7	138		3	10	0.07	6.5	8.43
		22-May-90	4.13	10.9	8.4	199	164	394	219	41	15	25	5.1	243		2.1	11	0.11	5.1	
		28-Aug-90	3.37	15.3	8.2	178	141	347	188	35	13	20	4.5	216	L1.	1.7	7	0.11	7.6	9.23
		09-Oct-90	1.22	5.8	8.5	208	163	402	225	39	16	29	4.5	254		1.7	10	0.12	7.9	
WOLF CREEK	00AL05FA0287	03-Apr-90	4.58	3.2	8.3	123	124	327	180	33	10	13	10.4	150		7.2	28	0.16	9.7	7.03
NEAR HWY 2		22-May-90	0.408	11.5	8.2	342	299	756	447	82	23	63	6	417		23.9	44	0.28	3	
		28-Aug-90	0.054	14.1	7.6	332	296	692	397	79	24	40	6	405		13.2	35	0.23	7.7	4.65
		09-Oct-90	0.054	6.4	8.4	359	334	775	452	91	26	47	5.9	438		21.7	45	0.24	11	
BATTLE RIVER (SITE 3)	00AL05FA0413	02-May-89	3.68	10.1	8.1	205	172	456	268	44	15	36	7.5	247	1	8.9	32	0.17	4.9	
NEAR HWY 2A, APPROX.		30-May-89	4.08	11.8	8.2	216	186	454	255	48	16	27	4.4	263		6.2	24	0.13	2.2	
18 KM D/S PONOKA		26-Jun-89	0.68	18.7	8.8	251	185	482	283	46	17	41	3.6	252	26	6.2	19	0.17	0.5	
		25-Jul-89	0.797	19.8	8.6	243	183	466	277	42	19	42	3.5	241	27	5.8	19	0.17	1.4	
		23-Aug-89	1.21	18.9	7.8	236	168	452	255	41	16	37	3.8	261	13	3.8	12	0.13	1.7	
		27-Sep-89	0.463	13.2	8.2	241	171	463	263	42	16	38	3.7	272	11	4.8	14	0.14	L.1	
		24-Oct-89	0.986	5.3	8.8	260	194	500	286	48	18	39	4.4	304	6	4.5	16	0.15	0.1	
		09-Jan-90	0.456	0	7.5	315	238	627	356	59	22	52	4.4	384		5.6	22	0.17	8.1	3.45
		03-Apr-90	28.7	3.8	8.4	110	99	254	136	25	9	8	10	134		4	12	0.09	7.2	8.01

STATION	CODE	DATE	DISCH.	TEMP.	PH	ALK TOT	HARD. TOT	SPEC. COND.	TDS	Ca	Mg	Na	K	HCO3	CO3	Cl	SO4	F	Si	DO
		D/M/Y	M3/S	DEG.C		mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
			97160S	02061F	10301F	10101L	10605L	02041L	00205L	20107L	12105L	11103L	19103L	06202L	06302L	17203L	16306L	09107L	14107L	08101L
		23-May-90	5.21	15.5	8.5															
		28-Aug-90	3.21	16.5	8.5	189	148	371	202	36	14	22	4.6	219	6	2.4	9	0.12	6.2	
		09-Oct-90	1.76	7	8.5	196	162	395	221	40	15	27	4.8	239		4.2	12	0.14	6.1	
BATTLE RIVER (SITE 4) D/S SAMSON LAKE	00AL05FA0500	02-May-89	10.8	10	8.8	172	143	392	231	36	13	27	9.6	165	22	9.8	32	0.15	1.3	
		30-May-89	6.8	13.3	8.4	223	183	480	273	47	16	32	6.4	265	3	7.8	30	0.15	2	
		26-Jun-89	2.67	17.7	8.8	211	162	432	248	35	18	36	4.9	233	12	5.9	22	0.16	0.8	
		25-Jul-89	0.319	19.7	9.3	187	93	428	247	11	16	61	5.6	156	35	10.5	31	0.22	4.8	
		23-Aug-89	0.646	18.7	8.7	182	82	387	220	13	12	55	5.8	114	53	8.1	17	0.19	16	
		27-Sep-89	0.47	14.2	8.9	203	122	417	238	21	17	48	5.4	213	17	7	17	0.18	3.8	
		24-Oct-89	0.463	5.4	9.1	220	146	453	258	27	19	46	5.5	248	10	6.5	22	0.17	0.1	
		09-Jan-90		-0.1	7.8	437	317	902	529	74	32	90	7.7	533		15	47	0.27	7	5.78
		03-Apr-90	17	2.2	8.5	118	102	275	147	26	9	11	9.9	144		5.1	13	0.11	6.3	6.92
		22-May-90	4.01	14.1	8.5	224	163	477	272	39	16	43	6.7	265	4	8	25	0.17	0.5	
		28-Aug-90	3.61	16.9	8.7	208	164	407	230	41	15	26	6.1	229	12	3.9	13	0.15	0.3	
		09-Oct-90	1.68	7	8.8	223	177	482	281	43	17	41	5.9	263	4	6.8	33	0.18	1	
PIPESTONE CREEK AT HWY 822	00AL05FA0600	03-Apr-90	16.8	0.9	8.5	104	89	278	150	24	7	17	9.4	127		7.1	22	0.14	6.3	9.3
		22-May-90	0.958	13.4	8.2	199	134	489	281	34	12	53	9.7	243		10.4	42	0.22	0.7	
		28-Aug-90	0.319	16.6	7.7	229	171	529	299	42	16	46	10	279		11.4	36	0.23	10.5	
		09-Oct-90	0.002	6.5	8.3	300	223	644	375	58	19	58	9.4	366		14.7	36	0.25	0.2	
BATTLE RIVER (SITE 5) AT HWY 21	00AL05FA0700	02-May-89	13.1	10.3	8.6	172	143	417	244	36	13	33	9.8	193	8	10	39	0.17	1.1	
		30-May-89	7.8	13	8.4	227	187	521	304	47	17	40	8.1	267	5	10.5	45	0.19	1.5	
		26-Jun-89	1.91	18.1	8.6	206	150	460	261	32	17	40	6.3	239	6	7.5	34	0.16	1.6	
		25-Jul-89	0.44	21.2	8.4	206	132	486	281	23	18	58	6.4	236	8	10.2	42	0.2	2.6	
		23-Aug-89	0.641	19.5	8	226	115	515	294	23	14	71	7.3	254	11	12.2	31	0.23	8.5	
		27-Sep-89	0.604	13.5	8.6	218	139	466	264	26	18	51	5.7	254	6	7	25	0.16	3.5	
		24-Oct-89	1.02	4.6	8.7	252	184	765	459	39	21	95	10	307		33.6	108	0.38	3.9	
		09-Jan-90		-0.2	7.8	438	324	953	570	77	32	101	7.9	534		17.8	69	0.29	8.8	7.69
		04-Apr-90	32.7	1.7	8.6	117	95	287	156	25	8	16	9.3	143		6.4	19	0.12	5.7	9.44
		22-May-90	6.17	14.9	8.5	224	168	501	288	41	16	47	7.4	260	7	9.2	33	0.19	0.5	
		28-Aug-90	4.57	16.1	8.3	237	185	483	271	46	17	34	6.8	286	2	5.1	20	0.16	1.2	
		09-Oct-90	2.22	6.3	8.5	239	186	516	299	45	18	43	6.1	291		6.6	37	0.18	1	
CAMROSE CREEK NEAR MOUTH	00AL05FA0745	04-Apr-90	1.15	1.4	8.5	118	149	612	357	35	15	63	11.5	144		29.6	130	0.15	6.4	10.94
		22-May-90	1.06	16.4	8.1	238	278	1023	642	67	27	118	13.8	290		46	222	0.25	2.3	
		28-Aug-90	0.159	16.8	8	199	205	717	437	46	22	72	12.3	243		13.1	151	0.2	8	
		09-Oct-90	0.239	6.9	8.6	277	324	1560	949	72	35	200	17.8	338		111	334	0.7	9	
BATTLE RIVER (SITE 6) D/S CAMROSE CR.	00AL05FA0750	02-May-89	14.046	10.4	8.2	175	153	473	274	38	14	40	10.3	208	3	14.2	52	0.18	1.9	
		30-May-89	7.98	13.4	8.4	234	197	545	320	51	17	42	7.8	275	5	11	51	0.18	1.6	
		26-Jun-89	1.936	18.1	8.5	211	159	484	277	34	18	43	6.6	257		8.1	41	0.17	2.5	
		25-Jul-89	0.491	21.2	8.3	217	169	588	349	33	21	68	7.7	251	7	15.5	74	0.2	2.8	
		23-Aug-89	0.65	19	7.5	214	115	523	302	23	14	72	6.8	254	3	11.5	46	0.24	7.6	
		27-Sep-89	0.608	13.2	8.1	219	131	470	267	26	16	54	6.2	267		8	25	0.17	8	
		24-Oct-89	1.028	5	8.4	272	204	701	418	47	21	81	7.7	332		23.1	75	0.25	2.3	

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE	DISCH.	TEMP.	PH	ALK TOT	HARD. TOT	SPEC. COND.	TDS	Ca	Mg	Na	K	HCO3	CO3	Cl	SO4	F	Si	DO
		D/M/Y	M3/S	DEG.C		mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
			97160S	02061F	10301F	10101L	10605L	02041L	00205L	20107L	12105L	11103L	19103L	06202L	06302L	17203L	16306L	09107L	14107L	08101L
		09-Jan-90		-0.1	7.8	451	327	991	592	75	34	106	8.2	550		19.6	76	0.3	9.2	6.82
		07-Feb-90		0.5	7.9	546	395	1126	680	89	42	116	8.7	666		19.6	75	0.3	9.5	3.31
		04-Apr-90	33.85	0.8	8.5	111	93	297	161	24	8	18	9.2	135		7.1	25	0.12	8.2	9.1
		22-May-90	7.23	15.4	8.5	227	177	530	308	43	17	49	7.7	259	9	11	44	0.2	0.6	
		28-Aug-90	4.729	16.3	8.2	244	191	511	288	47	18	36	7.1	297		5.6	28	0.16	1.8	10.09
		09-Oct-90	2.459	6.2	8.6	236	206	623	362	48	21	55	7.4	288		18.3	69	0.22	1.6	
BATTLE RIVER (SITE 7)	00AL05FA1000	03-May-89	20.4	8.9	8.5	175	143	456	265	36	13	40	9.7	212	L1.	13.8	46	0.17	5.5	
AT HWY 850		30-May-89	7.98	13.4	8.4	185	159	485	286	39	15	41	9.7	218	3	13.2	57	0.18	0.3	
		26-Jun-89	1.16	18.4	8.8	208	176	536	319	41	18	49	9	224	14	12.6	65	0.2	2.9	
		25-Jul-89	0.77	20.7	8.1	208	162	521	301	37	17	52	7.7	254		12.1	50	0.22	14	
		24-Aug-89	0.145	14.2	7.1	230	143	545	308	34	14	62	10.8	280		17.9	31	0.3	7	
		27-Sep-89	0.413	16.3	9.6	206	146	503	311	32	16	57	10.1	142	54	15.2	57	0.22	11.9	
		24-Oct-89	0.19	5.9	7.9	228	161	581	346	38	16	60	10	278		15.8	67	0.22	5.2	
		10-Jan-90		0.3	7.9	277	231	732	435	48	27	72	10.1	338		15.9	95	0.22	8.7	3.52
		04-Apr-90	29.2	2.7	8.3	278	221	722	423	49	24	73	9.4	339		18.4	81	0.23	1.6	6.9
		28-May-90	6.39	17.7	8.3	193	163	499	289	39	16	43	10	230	3	11.7	53	0.18	1.4	7.7
		29-Aug-90	7.85	16.1	8.3	218	187	463	269	47	17	32	8.3	266		6.3	27	0.15	6.6	
		10-Oct-90	1.82	5.3	9.2	227	194	498	298	48	18	37	8.5	277		6.7	43	0.17	L.1	
MEETING CREEK	00AL05FC0290	05-Apr-90	2.8	2.5	8.6	71	46	234	139	12	4	28	7.3	87		5.7	36	0.13	6.2	10.27
NEAR MOUTH		28-May-90	0.034	15.6	8.2	360	230	902	553	59	20	121	9.4	439		22.1	105	0.26	7.4	
		29-Aug-90	0.001	13.9	8	365	194	859	529	48	18	133	9.7	445		13.2	88	0.25	6.9	
		10-Oct-90	L .001	5.3	8.5	465	190	1049	652	48	17	178	10.2	567		15.2	105	0.3	5.1	
BIG KNIFE CREEK	00AL05FC0400	28-May-90	1.32																	
NEAR MOUTH																				
BATTLE RIVER (SITE 8)	00AL05FC0660	03-May-89	19	10.7	8	145	120	390	221	30	11	32	9.3	177		11.5	39	0.14	5.5	
IN BIG KNIFE PROV.P.		30-May-89	7.03	13.2	8.6	186	159	490	287	39	15	42	9.5	222	2	13.1	57	0.18	L.1	
U/S FORESTBURG		27-Jun-89	2.73	17.5	7.9	222	184	564	327	44	18	52	10.1	271		13.8	56	0.2	6	
		26-Jul-89	1.16	22.4	8	191	114	489	287	29	10	62	7.7	224	4	8.2	55	0.2	9.1	
		24-Aug-89	0.41	20.4	8.4	219	151	592	352	34	16	72	10.2	236	15	12.5	76	0.26	10.8	
		28-Sep-89	0.221	18.5	8.7	241	171	670	409	39	18	85	11	246	24	16	95	0.29	7.2	
		24-Oct-89	0.586	15.4	8.5	252	190	728	444	43	20	88	11.4	278	14	18	112	0.29	7.9	
		10-Jan-90		0.2	7.7	288	234	757	447	49	27	76	9.9	351		15.4	96	0.23	8.3	1.81
		05-Apr-90	31.4	1.3	8.3	217	171	601	356	39	18	66	8.9	265		17	76	0.22	7.1	8.01
		28-May-90	6.98	18	8.3	201	166	510	295	40	16	44	9.9	235	5	11.4	53	0.18	2.2	
		29-Aug-90	6.62	18.3	8.6	229	196	480	283	49	18	34	8.4	279		6.7	29	0.16	6.1	
		10-Oct-90	1.99	6.4	8.9	237	201	521	308	49	19	40	8.9	289		7.3	42	0.17	L.1	
BATTLE RIVER (SITE 9)	00AL05FC0680	03-May-89	18.3	15.7	8.2	184	152	512	297	36	15	50	9.5	224		17	56	0.17	5.5	
AT HWY 861		31-May-89	6.4	17.1	8.7	182	154	483	282	37	15	44	9.2	203	9	13.8	54	0.19	0.2	
D/S FORESTBURG RES.		27-Jun-89	4.13	17.2	8.4	199	161	529	308	38	16	50	10.2	230	6	14.9	59	0.2	2.4	
		26-Jul-89	2.05	21.9	8.2	202	138	536	317	32	14	63	9.4	227	9	12.2	65	0.23	4.8	
		24-Aug-89	0.007	16.3	7.4	228	150	675	398	32	17	87	10	273	2	16.5	99	0.24	5	
		28-Sep-89	0.015	13.2	7.9	263	172	763	463	36	20	107	10	321		20.3	112	0.26	5.7	

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE	DISCH.	TEMP.	PH	ALK TOT	HARD. TOT	SPEC. COND.	TDS	Ca	Mg	Na	K	HC03	CO3	Cl	SO4	F	Si	DO
		D/M/Y	M3/S 97160S	DEG.C 02061F	10301F	mg/L 10101L	mg/L 10605L	uS/cm 02041L	mg/L 00205L	mg/L 20107L	mg/L 12105L	mg/L 11103L	mg/L 19103L	mg/L 06202L	mg/L 06302L	mg/L 17203L	mg/L 16306L	mg/L 09107L	mg/L 14107L	mg/L 08101L
		24-Oct-89	0.076	5.2	8	267	176	777	467	39	19	100	11	325		20	118	0.24	4	
		10-Jan-90		0	8.3	259	207	784	474	45	23	92	11.3	316		19.4	123	0.29	6.8	9.62
		05-Apr-90	41.9	7.3	8	107	80	322	188	19	8	36	7.4	130		7.1	45	0.12	5.2	9.11
		28-May-90	5.9	18.2	8.5	187	159	486	281	39	15	41	9.7	215	6	10.2	54	0.18	0.3	9.15
		29-Aug-90	7.89	20	8.2	220	192	480	280	49	17	34	8.4	268		6.6	32	0.16	3.2	
		10-Oct-90	2.12	8.4	8.7	240	207	544	324	50	20	43	9.2	279	7	8	49	0.19	2	
PAINTEARTH CREEK AT MOUTH	00AL05FC0690	05-Apr-90	0.994	3.4	8.3	50	23	185	110	6	2	28	4.5	61		2.2	37	0.1	5.3	11.46
		28-May-90	0.002	19.3	8	216	138	783	480	37	11	118	7.8	263		10.7	166	0.25	9.2	
		29-Aug-90	0.003	17.6	7.9	245	185	812	510	51	14	116	8.4	299		10.7	163	0.28	15.3	
CASTOR CREEK NEAR MOUTH	00AL05FC0800	05-Apr-90	1.91	4	8.2			231												11.07
		28-May-90	0.005	19.1	8	422	227	1257	811	58	20	212	9.3	501	6	15.4	243	0.34	6	
		29-Aug-90		19.6	8.1			1272												
BATTLE RIVER (SITE 10) AT HWY 872	00AL05FC1000	03-May-89	18.6	15.2	8.3	198	158	556	322	37	16	58	9.4	241		18.8	61	0.18	4.7	
		31-May-89	6.47	16	8.7	189	157	503	293	38	15	47	9.4	219	6	14.2	56	0.19	0.5	
		27-Jun-89	2.99	17.5	8.6	195	160	530	312	36	17	53	10.1	212	12	15.3	64	0.21	2.5	
		26-Jul-89	1.64	22	8.3	211	147	570	338	34	15	67	10	234	12	13.3	72	0.24	6.6	
		22-Aug-89	0.045	23	8.4	259	189	737	448	36	24	95	9.6	283	16	15.1	113	0.25	2.3	
		28-Sep-89	0.055	14.9	8.2	270	213	781	481	44	25	96	9.4	308	10	14	131	0.26	2.8	
		24-Oct-89	0.054	6.8	8.3	289	227	898	562	48	26	114	10.4	333	10	19.3	171	0.26	2.2	
		10-Jan-90		-0.1	8	279	219	843	510	48	24	102	11	340		20.1	133	0.3	7.6	5.99
		07-Feb-90		0.2	8.2	372	314	1100	687	68	35	133	12.5	453		25.2	185	0.34	9.7	2.62
		05-Apr-90	42.9	7.6	8.2	100	70	305	179	18	6	35	7.2	122		5	46	0.14	5.1	8.28
		28-May-90	5.71	19.4	8.3	191	163	500	291	39	16	43	10	227	3	10	58	0.18	1.4	8.7
		29-Aug-90	7.68	19.9	8.5	226	199	493	292	50	18	36	8.5	271	2	6.8	37	0.17	2.6	
		10-Oct-90	1.94	7.1	8.7	248	212	572	340	52	20	47	9	288	7	8.2	55	0.19	2.9	
GRATTAN CREEK NEAR MOUTH	00AL05FE0175	10-Apr-90		0.5	8.1															
		29-May-90	0	16.6	7.8	933	324	1850	1204	44	52	370	9.3	1137		6.4	162	0.36	19.4	
		30-Aug-90		17.1	8.7															
BATTLE RIVER (SITE 11) D/S HARDISTY	00AL05FB0500	03-May-89		14.1	8.2	216	167	612	356	39	17	66	9.5	253	5	20.1	73	0.2	4.5	
		31-May-89	6.46	16.6	8.4	209	172	551	323	41	17	52	9.6	249	3	15.2	63	0.2	1.4	
		27-Jun-89	3.563	17.9	8.3	214	171	576	339	39	18	60	9.7	253	4	15.2	69	0.22	4	
		26-Jul-89	2.53	22.6	8.2	238	172	629	375	41	17	72	10.3	276	7	15	77	0.26	8.1	
		22-Aug-89	0.177	22	8	303	217	801	482	44	26	98	9.3	350	9	19.4	103	0.24	4.6	
		28-Sep-89	0.168	14.3	8.2	327	254	886	545	49	32	107	7.8	371	14	19.8	133	0.24	4.2	
		24-Oct-89	0.19	7	8.2	354	281	951	594	58	33	110	7.7	408	12	21	152	0.24	5.4	
		10-Jan-90		-0.1	7.7	329	257	951	577	55	29	113	12.3	401		20.7	146	0.32	9.9	5.97
		10-Apr-90	34.4	4.1	8.3	162	122	477	269	29	12	50	7.9	197		10.2	61	0.16	6.4	10.28
		28-May-90	7.27	19.6	8.2	199	168	522	300	41	16	45	10	243		9.8	59	0.18	3.3	
		29-Aug-90	9.13	18.9	8.4	235	204	510	303	52	18	38	8.4	286		6.8	39	0.17	1.9	
		10-Oct-90	2.62	6.8	8.7	262	224	608	366	55	21	51	8.7	306	6	9	64	0.2	3.6	
IRON CREEK	00AL05FB0700	10-Apr-90	3	2.5	8.4	195	143	548	316	26	19	62	8.1	238		5.8	78	0.11	11.1	10.72

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE	DISCH.	TEMP.	PH	ALK TOT	HARD. TOT	SPEC. COND.	TDS	Ca	Mg	Na	K	HCO3	CO3	Cl	SO4	F	Si	DO
		D/M/Y	M3/S	DEG.C		mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
			97160S	02061F	10301F	10101L	10605L	02041L	00205L	20107L	12105L	11103L	19103L	06202L	06302L	17203L	16306L	09107L	14107L	08101L
NEAR HARDISTY		28-May-90	0.106	19.9	8.3	495	361	1150	731	59	52	145	12.6	577	13	10.4	155	0.19	6.6	9.05
		29-Aug-90	0.017	16.5	8.5	596	400	1630	1093	58	62	260	16.1	702	12	18.7	320	0.2	13.1	
		10-Oct-90	0.002	7	8.8	659	438	1880	1267	55	73	300	19.3	770	16	22.8	401	0.23	14.8	
BATTLE RIVER (SITE 12)	00AL05FE0400	04-May-89		12.1	8.1	224	176	633	377	41	18	72	9.5	263	5	21	79	0.21	4.7	
AT HWY 41		31-May-89	6.521	16.4	8.3	241	193	625	370	46	19	63	9.2	288	3	15.4	73	0.2	3	
		27-Jun-89	3.813	18.6	8.4	244	181	646	386	41	19	75	8.7	273	12	15.8	80	0.22	6.2	
		26-Jul-89	2.535	24.2	8.5	235	158	616	372	37	16	78	9.2	253	16	13	78	0.24	6.9	
		22-Aug-89	0.178	23.5	8.5	322	185	851	520	33	25	128	8	342	25	21.4	111	0.25	2.6	
		28-Sep-89	0.179	15.2	8.3	368	213	936	568	36	30	130	6.8	414	17	22	122	0.24	4.1	
		24-Oct-89	0.245	7.2	8.4	386	276	952	592	61	30	119	5.8	441	14	18.4	126	0.22	8.6	
		11-Jan-90		0.3	7.8	410	329	1086	677	74	35	130	10.3	500		24	155	0.31	14.4	4.76
		10-Apr-90	37.7	3.6	8.3	147	101	437	236	24	10	48	7.6	179		8	49	0.15	6.6	10.15
		29-May-90	7.73	18.1	8.2	226	188	579	342	44	19	55	9.8	276		10	69	0.19	5.1	8.03
		30-Aug-90	10.7	17.9	8.3	248	204	543	317	52	18	42	7.9	302		6.7	42	0.18	4.4	8.9
		11-Oct-90	4.2	4.6	8.7	297	250	687	416	59	25	64	7.7	346	8	8.8	73	0.2	5.9	
BUFFALO CREEK	00AL05FE0500	10-Apr-90	0.653	0.7	8.4															
AT HWY 41		29-May-90	0.1	17.6	8	609	493	1610	1083	77	73	225	5.7	718	12	2.7	334	0.23	9.8	
		30-Aug-90	0.005	17	8.3															
		11-Oct-90	0.015	4.6	8.6															
GRIZZLY BEAR CREEK	00AL05FE0600	10-Apr-90		0.8	8.8															
NEAR MOUTH		29-May-90	0.003	18.4	8.7	836	560	2370	1643	46	108	405	15.7	881	68	38.9	528	0.22	0.8	
		30-Aug-90		17.2	9.7															
BATTLE RIVER (SITE 13)	00AL05FE0850	04-May-89	21.1	12.3	8.3	244	190	700	420	43	20	83	9.6	260	18	22.8	94	0.23	4.2	
AT HWY 897		31-May-89	7.7	17.6	8.3	269	210	716	433	48	22	78	9.3	316	6	16.9	97	0.22	3.5	
		27-Jun-89	5.44	19	8.5	259	186	684	409	40	21	81	8.8	295	10	17.8	85	0.22	6.5	
		26-Jul-89	4.27	24.9	8.8	222	145	638	390	30	17	90	8.5	226	22	12.1	99	0.24	2.9	
		22-Aug-89	1.19	22.9	8.6	348	182	931	574	30	26	151	8.5	370	27	25.2	124	0.25	1.2	
		28-Sep-89	1.11	15.1	8.3	402	220	1064	656	37	31	163	7.5	465	12	28.1	148	0.24	0.7	
		24-Oct-89	1.11	7.4	8.3	419	271	1074	676	54	33	155	6.3	484	13	24.6	152	0.24	5.3	
		11-Jan-90		0	7.7	460	356	1198	756	80	38	149	9.2	561		24.5	177	0.3	15.5	2.68
		10-Apr-90	41.7	3.6	8.3	135	92	401	228	21	10	45	7.3	165		5.6	57	0.14	6.2	9.67
		29-May-90	8.77	19.7	8.3	239	207	614	374	50	20	62	9.8	281	5	10.8	78	0.2	5.7	8.28
		30-Aug-90	11.5	18.8	8.4	252	201	556	325	51	18	45	8.2	307		7.1	44	0.19	5.8	
		11-Oct-90	4.16	4.8	8.8	337	273	809	498	65	27	84	8.1	388	11	13.9	98	0.21	7.1	
RIBSTONE CREEK	00AL05FE0875	10-Apr-90	0.159	0.5	8.5	195	145	467	264	30	17	45	5.1	238		4.5	45	0.17	8.8	12.88
AT HWY 14		29-May-90	1.38	20.2	8.3	327	282	670	400	60	32	50	6.4	380	9	4.5	51	0.32	9.1	
		30-Aug-90	0.186	19.1	8.5	397	286	718	424	55	36	68	4.4	455	14	4.6	18	0.31	6.3	
		11-Oct-90	0.008	4.7	8.7	467	314	945	579	58	41	115	5.2	550	10	9.5	70	0.34	3.2	
BLACKFOOT CREEK	00AL05FE0890	10-Apr-90		2	8.4															
AT UNWIN ROAD		29-May-90	0.003	22.7	8.3	551	467	1760	1205	70	71	248	13.7	629	21	9.2	462	0.28	4.9	

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE	DISCH.	TEMP.	PH	ALK TOT	HARD. TOT	SPEC. COND.	TDS	Ca	Mg	Na	K	HCO3	CO3	Cl	SO4	F	Si	DO
		D/M/Y	M3/S	DEG.C		mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
			97160S	02061F	10301F	10101L	10605L	02041L	00205L	20107L	12105L	11103L	19103L	06202L	06302L	17203L	16306L	09107L	14107L	08101L
BATTLE RIVER (SITE 14)	00SA05FE1000	04-May-89	21.4	12.2	7.2	250	192	721	438	44	20	88	9.8	283	11	22.9	102	0.23	4.2	
AT UNWIN		30-May-89	9.22	17.6	8.5	276	221	724	438	49	24	77	9.1	320	8	16.2	97	0.21	5	
		28-Jun-89	5.21	17.9	8.4	285	207	717	433	45	23	84	8.5	330	9	17.2	84	0.24	6.7	
		03-Aug-89	4.22	20.9	8.6	269	170	725	438	35	20	98	8.8	296	16	18.1	97	0.25	6.7	
		22-Aug-89	1.33	20.5	8.4	339	204	930	568	37	27	140	8.7	372	20	27.2	125	0.25	3.7	
		26-Sep-89	1.22	12.5	8.6	404	232	1081	679	40	32	167	7.1	450	21	30	160	0.24	1.3	
		24-Oct-89	1.15	5.5	7.9	426	274	1167	726	52	35	170	6.8	465	27	31.2	175	0.24	3.5	
		11-Jan-90	1.4	0	7.8	481	380	1252	795	83	42	158	8.8	586		26.2	187	0.28	15.5	2.27
		08-Feb-90	0.672	0.4	8.2															0.16
		10-Apr-90	43.5	3.8	8.3	132	89	391	224	20	10	44	7.5	161		5.1	57	0.16	5.9	9.28
		29-May-90	103	19.8	8.4	251	204	631	380	47	21	63	9.7	290	8	10.3	78	0.21	5.8	8.68
		30-Aug-90	11.5	18.6	8.4	255	194	563	319	48	18	46	8.2	306	2	7.2	39	0.19	6.6	8.9
		11-Oct-90	4.42	4.7	8.9	342	278	823	516	65	28	92	8.2	391	13	13.9	104	0.22	8.3	
BATTLE RIVER (SITE 15)	00SA05FF1000	04-May-89	22.4	13.2	8.4	255	196	760	464	44	21	97	9.5	279	16	21	118	0.24	3	
AT HWY 40		30-May-89	11.5	17.3	8.5	294	244	808	502	55	26	91	9.3	335	11	16.4	128	0.21	4.5	
NEAR MOUTH		28-Jun-89	7.05	21.7	8.4	287	224	740	450	47	26	84	8.8	326	12	16.2	96	0.24	8.5	
		03-Aug-89	5.96	19.8	8.5	245	169	686	413	33	21	87	8.2	270	14	15.8	101	0.25	6.5	
		22-Aug-89	2.7	22.1	8.6	262	169	750	454	28	24	106	8.4	271	24	18.2	112	0.23	3.2	
		26-Sep-89	2.15	12.2	8.6	331	217	972	613	39	29	147	7.3	362	21	28.8	163	0.23	0.6	
		24-Oct-89	1.62	6.5	8.4	382	281	1105	706	53	36	153	7.3	433	16	30	197	0.24	0.5	
		11-Jan-90		-0.1	7.7	553	468	1480	958	100	53	182	8.2	674		29.3	253	0.28	14.7	1.08
		08-Feb-90		0.2	7.9	573	476	1500	978	105	52	183	10	698		30.7	253	0.33	19.3	
		10-Apr-90	52	4.4	8.4	155	101	461	271	23	11	55	7.8	189		7.4	72	0.16	5.8	9.61

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE	DO	BOD	COD	NFR	FR	TURB.	COLOUR TRUE	TAN.& LIGN.	OIL GREASE	PHENOL-IC MAT.
		D/M/Y	mg/L 08102F	mg/L 08202L	mg/L 08304L	mg/L 10401L	mg/L 10451L	NTU 02074L	RCU 02024L	mg/L 06551L	mg/L 06524L	mg/L 06537L
PIGEON L. CREEK	00AL05FA0225	03-Apr-90	8.8									
EAST OF HWY 611		22-May-90	9.7	1.6	24	65	272	37	14	0.29	L1.0	0.002
		28-Aug-90	9									
		09-Oct-90	11.2									
BATTLE RIVER (SITE 1)	00AL05FA0250	02-May-89	10.5	1.8	32	2	300		32	0.62	0.5	0.008
AT HWY 611		30-May-89	8.1	1.6	30	8	240		24	0.5	0.2	0.008
		26-Jun-89	7.7	1.9	34	5	258		23	0.55	1	0.008
		25-Jul-89		1.7	30	5	240		28	0.74	1	0.009
		23-Aug-89	6	0.6	34	2.4	254		40	0.9	L.1	L.001
		27-Sep-89	4.7	3	37	6	254		24	0.82	L1.0	0.01
		24-Oct-89	8.3	2.2	28	4	258		22	0.48	L1.0	0.004
		09-Jan-90	4.8	1.5	19	5	230		20	0.39	L1.0	0.004
		07-Feb-90	2.6	1	28	5	262		20	0.38	L1.0	0.007
		03-Apr-90	9.8	7.2	40	30	180	15.9	53	1.2	L1.0	0.016
		22-May-90	8.2	2	28	11	266	6.8	26	0.64	L1.0	0.005
		28-Aug-90	8.5	1.5	27	8	268	4.9	33	0.79	L.1	0.007
		09-Oct-90	10.7	4	35	12	298	8.1	30	0.76	L.1	0.008
BATTLE RIVER (SITE 2)	00AL05FA0280	02-May-89	9	3.7	52	40	266		70	1.3	0.7	0.015
AT HWY 53, U/S PONOKA		30-May-89	8.6	1.6	42	22	296		51	0.88	0.1	0.01
		26-Jun-89	8.8	1.8	37	9	314		33	0.8	L1.0	0.008
		25-Jul-89	7.9	0.8	35	7	290		51	1.01	L1.0	0.01
		23-Aug-89		0.7	39	3.9	300		40	1.2	L.1	L.001
		27-Sep-89	10	4.1	37	7	270		29	L.05	L1.0	0.012
		24-Oct-89	9.8	2.4	26	4	322		25	0.72	L1.0	0.005
		09-Jan-90	0	0.8	21	4	308		23	0.64	L1.0	0.006
		06-Feb-90	0	0.89	27	6	364		15	0.47	L1.0	0.006
		03-Apr-90	9	8.9	59	83	284	40	97	2.03	L1.0	0.021
		22-May-90	8.1	1.6	28	7	274	7.9	29	0.66	L1.0	0.006
		28-Aug-90	8.7	1.8	23	12	248	6.7	17	0.38	0.1	0.005
		09-Oct-90	11.2	1.3	24	11	252	8.6	11	0.33	L.1	0.004
WOLF CREEK	00AL05FA0287	03-Apr-90	7.8	8.6	53	13	244	5.4	110	2.21	L1.0	0.026
NEAR HWY 2		22-May-90	8.5	2.9	44	9	496	3.4	53	0.68	L1.0	0.009
		28-Aug-90	3.8	1.7	37	5	470	3.8	50	0.82	L.1	0.008
		09-Oct-90	8.2	3.3	36	7	498	5.4	35	0.65	L.1	0.006
BATTLE RIVER (SITE 3)	00AL05FA0413	02-May-89	12.7	5.3	53	19	344		80	1.46	0.5	0.016
NEAR HWY 2A, APPROX.		30-May-89	9.4	2.8	48	13	314		56	1	0.3	0.012
'8 KM D/S PONOKA		26-Jun-89	12.2	2.4	38	3	330		35	0.76	L1.0	0.009
		25-Jul-89	8.4	1	38	4	318		47	0.94	L1.0	0.01
		23-Aug-89	9	1.5	49	4.4	336		50	1.2	L.1	L.001
		27-Sep-89	9.7	3.2	39	6	296		30	0.38	L1.0	0.011
		24-Oct-89	10.4	3.6	32	4	330		25	0.65	L1.0	0.007
		09-Jan-90	2.9	0.7	19	4	362		22	0.28	L1.0	0.003
		03-Apr-90	8.9	7.7	56	53	290	23	95	2.05	L1.0	0.025

STATION	CODE	DATE	DO	BOD	COD	NFR	FR	TURB.	COLOUR TRUE RCU	TAN.& LIGN.	OIL GREASE	PHENOL-IC MAT.
		D/M/Y	mg/L 08102F	mg/L 08202L	mg/L 08304L	mg/L 10401L	mg/L 10451L	NTU 02074L	02024L	mg/L 06551L	mg/L 06524L	mg/L 06537L
		23-May-90	13.4									
		28-Aug-90	10.8	1.9	28	14	278	4	19	0.47	L.1	0.005
		09-Oct-90	11.2	1.5	23	7	250	5.8	9	0.33	L.1	0.004
BATTLE RIVER (SITE 4) D/S SAMSON LAKE	00AL05FA0500	02-May-89	11.3	6.5	68	27	306		99	1.81	0.5	0.025
		30-May-89	8.5	4	53	23	340		56	1.05	0.2	0.013
		26-Jun-89	10.9	3.2	45	10	304		33	0.66	1	0.013
		25-Jul-89	9.7	7.8	52	27	324		51	0.94	L1.0	0.016
		23-Aug-89	9	10	113	41.8	326		50	1.3	L.1	0.001
		27-Sep-89	9.7	7.5	76	16	300		43	0.63	L1.0	0.019
		24-Oct-89	10.8	7.8	69	18	346		32	0.65	L1.0	0.007
		09-Jan-90	5.5	1.6	39	4	550		35	0.44	L1.0	0.007
		03-Apr-90	7.8	7.9	71	55	262	17	94	2.04	L1.0	0.026
		22-May-90	9.6	5.3	50	23	332	24	43	0.87	L1.0	0.008
		28-Aug-90	12.3	2.6	37	15	304	9.5	34	0.85	1	0.008
		09-Oct-90	12.9	2.2	33	14	316	14	20	0.53	L.1	0.006
PIPESTONE CREEK AT HWY 822	00AL05FA0600	03-Apr-90	10.4	9.9	70	181	342	69	82	1.7	L1.0	0.021
		22-May-90	9.7	3.1	47	10	328	7.4	38	0.79	L1.0	0.01
		28-Aug-90	6.9	3.8	55	12	398	9.1	46	1.26	0.1	0.011
		09-Oct-90	9.6	5	57	29	558	14.1	37	0.72	L.1	0.012
BATTLE RIVER (SITE 5) AT HWY 21	00AL05FA0700	02-May-89	9.4	5.5	68	166	454		80	1.54	0.7	0.02
		30-May-89	9	3.8	52	48	396		49	0.98	0.2	0.013
		26-Jun-89	9.8	5.8	65	21	344		38	0.73	1	0.016
		25-Jul-89	8.3	4.3	61	24	346		41	0.94	L1.0	0.014
		23-Aug-89	8.6	8.8	98	42.9	481		30	1.3	L.1	0.002
		27-Sep-89	9.1	5.4	62	15	314		36	0.76	L1.0	0.018
		24-Oct-89	10.7	4.4	61	20	512		32	0.79	L1.0	0.008
		09-Jan-90	8.2	1	39	11	608		32	0.47	L1.0	0.008
		04-Apr-90	10	10.9	78	236	510	140	74	1.8	L1.0	0.02
		22-May-90	9.9	4	45	21	334	14.5	37	0.87	L1.0	0.009
		28-Aug-90	9.8	2.7	41	27	358	17.9	36	1.06	0.1	0.009
		09-Oct-90	11.7	2.4	34	21	346	16.5	19	0.75	L.1	0.007
CAMROSE CREEK NEAR MOUTH	00AL05FA0745	04-Apr-90	11.5	7.5	81	136			72	1.69	L1.0	0.021
		22-May-90	10.4	9.2	61	39			64	0.89	L1.0	0.011
		28-Aug-90	8.4	3.2	59	44			72	2	L.1	0.015
		09-Oct-90	10.9	21.5	72	47			33	0.68	L.1	0.013
BATTLE RIVER (SITE 6) D/S CAMROSE CR.	00AL05FA0750	02-May-89	8.9	6.5	68	87	416		76	1.6	0.4	0.019
		30-May-89	9.1	3.6	57	37	416		49	1	0.3	0.013
		26-Jun-89	9.2	5.1	64	27	370		37	0.78	1	0.014
		25-Jul-89	8	3.6	55	16	412		43	0.95	1	0.013
		23-Aug-89	8.9	3	88	27.4	485		50	1.3	L.1	0.002
		27-Sep-89	7.1	5.4	68	14	328		37	1.78	L1.0	0.017
		24-Oct-89	10.4	2.9	50	17	572		33	0.92	L1.0	0.008

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE	DO	BOD	COD	NFR	FR	TURB.	COLOUR TRUE	TAN.& LIGN.	OIL GREASE	PHENOL-IC MAT.
		D/M/Y	mg/L 08102F	mg/L 08202L	mg/L 08304L	mg/L 10401L	mg/L 10451L	NTU 02074L	RCU 02024L	mg/L 06551L	mg/L 06524L	mg/L 06537L
		09-Jan-90	6.3	1.4	39	8	644		35	0.44	L1.0	0.007
		07-Feb-90	3.5	1.2	55	9	714		36	0.66	L1.0	0.011
		04-Apr-90	9.6	9.2	77	280	514	143	70	1.75	L1.0	0.02
		22-May-90	11.2	4.3	46	20	366	14.4	45	0.9	L1.0	0.009
		28-Aug-90	9.7	2.6	41	24	388	15.4	40	1.14	0.1	0.01
		09-Oct-90	12.4	5.2	37	19	412	13.4	21	0.85	L.1	0.008
BATTLE RIVER (SITE 7) AT HWY 850	00AL05FA1000	03-May-89	13.2	8	70	39	360		73	1.44	0.4	0.02
		30-May-89	9.7	6.6	61	22	354		44	0.9	0.3	0.014
		26-Jun-89	15.8	2.6	56	3	388		46	0.8	L1.0	0.018
		25-Jul-89	12.1	1.9	64	11	376		50	1.27	L1.0	0.015
		24-Aug-89	1.9	5	78	35.4	417		70	1.3	L.1	0.004
		27-Sep-89	12.3	8	88	35	400		52	0.6	L1.0	0.019
		24-Oct-89	5.5	7.2	115	318	640		23	0.71	L1.0	0.01
		10-Jan-90	3		48						L1.0	0.007
		04-Apr-90	7.1	6.1	54	41	536	27	42	1.16	L1.0	0.013
		28-May-90	7.5	3.6	66	22	354	10.5	46	0.75	L1.0	0.011
		29-Aug-90	7.2	6.3	65	92	454	57	45	1.21	0.3	0.009
		10-Oct-90	11.2	9.7	84	143	474	83	32	0.9	L.1	0.017
MEETING CREEK NEAR MOUTH	00AL05FC0290	05-Apr-90	10.8	6.8	56	168	428	159	43	1.86	L1.0	0.017
		28-May-90	7.4	2.8	44	11	620	11.9	53	0.93	L1.0	0.01
		29-Aug-90	4.1	2.6	53	60	666	40	65	1.38	L.1	0.011
		10-Oct-90	5.5	3.4	55	14	710	10.7	74	1.46	L.1	0.018
BIG KNIFE CREEK NEAR MOUTH	00AL05FC0400	28-May-90							37	0.8	L1.0	0.008
BATTLE RIVER (SITE 8) IN BIG KNIFE PROV.P. U/S FORESTBURG	00AL05FC0660	03-May-89	10.8	7.4	60	39	322		67	1.43	0.5	0.018
		30-May-89	9.9	5.8	54	20	348		44	0.85	0.2	0.014
		27-Jun-89	6.8	3.8	38	16	392		36	0.72	L1.0	0.013
		26-Jul-89	5.5	2.7	37	13	362		77	1.41	L1.0	0.012
		24-Aug-89	8.3	3.4	69	29.1	415		50	0.9	L.1	0.002
		28-Sep-89	10.2	4.5	62	21	548		48	0.68	L1.0	0.013
		24-Oct-89	8.5	4.6	63	28	530		45	0.71	L1.0	0.007
		10-Jan-90	0.2	1.3	50	6	516		36	0.76	2.3	0.008
		05-Apr-90	9.1	7.7	51	130	532	99	41	1.04	L1.0	0.01
		28-May-90	10.3	4.6	50	28	370	20	45	0.76	L1.0	0.01
		29-Aug-90	14.9	4.6	49	21	392	14.2	48	1.27	L.1	0.01
		10-Oct-90	11.4	6.2	52	18	358	12.1	38	0.92	L.1	0.01
BATTLE RIVER (SITE 9) AT HWY 861 D/S FORESTBURG RES.	00AL05FC0680	03-May-89	9.7	7.8	60	79	462		62	1.29	0.5	0.015
		31-May-89	9.2	3.8	50	28	374		41	0.8	L1.0	0.012
		27-Jun-89	8.3	3.4	40	21	376		36	0.77	3	0.014
		26-Jul-89	7.6	1.7	35	45	414		45	0.92	L1.0	0.009
		24-Aug-89	6	1.8	49	26.7	549		40	1	L.1	0.001
		28-Sep-89	7.9	3.3	62	34	526		33	0.76	L1.0	0.011

STATION	CODE	DATE	DO	BOD	COD	NFR	FR	TURB.	COLOUR TRUE	TAN.& LIGN.	OIL GREASE	PHENOL-IC MAT.
		D/M/Y	mg/L 08102F	mg/L 08202L	mg/L 08304L	mg/L 10401L	mg/L 10451L	NTU 02074L	RCU 02024L	mg/L 06551L	mg/L 06524L	mg/L 06537L
		24-Oct-89	9.7	3	50	31	536		35	0.74	L1.0	0.007
		10-Jan-90	9.1	2.9	50	22	552		38	0.76	1.5	0.007
		05-Apr-90	9.5	8.5	81	322	694	240	50	1.35	L1.0	0.011
		28-May-90	9.5	3.9	44	30	356	16	45	0.71	L1.0	0.01
		29-Aug-90	8.6	2.7	47	32	400	25	45	1.15	L1	0.008
		10-Oct-90	11.1	1.8	41	13	374	8.3	40	1.06	L1	0.009
PAINTEARTH CREEK AT MOUTH	00AL05FC0690	05-Apr-90	11.9	6	53	134	442	176	100	1.84	L1.0	0.014
		28-May-90	9.6	3.1	41	12	584	32	52	0.74	L1.0	0.009
		29-Aug-90	9	2.4	40	27	620	27	49	1.12	L1	0.007
CASTOR CREEK NEAR MOUTH	00AL05FC0800	05-Apr-90	12.2									
		28-May-90	7.5	2.8	39	17	890	9	35	0.71	L1.0	0.008
		29-Aug-90	8.9									
BATTLE RIVER (SITE 10) AT HWY 872	00AL05FC1000	03-May-89	9.9	7.7	65	210	564		54	1.12	0.4	0.01
		31-May-89	9.4	3.6	50	33	386		41	0.75	1	0.012
		27-Jun-89	8.9	2.1	37	16	368		36	0.65	L1.0	0.011
		26-Jul-89	9	2	30	14	412		48	0.81	L1.0	0.008
		22-Aug-89	13	0.5	39	2.1	590		30	0.8	L1	0.001
		28-Sep-89	10.9	1.4	40	7	514		25	0.52	L1.0	0.008
		24-Oct-89	12.1	2.4	34	18	610		23	0.51	L1.0	0.005
		10-Jan-90	5.4	1.6	49	22	590		41	0.44	1.1	0.007
		07-Feb-90	2.3	1.4	59	24	766		41	0.45	L1.0	0.015
		05-Apr-90	8.8	8.6	101	868	1056	365	56	1.53	L1.0	0.011
		28-May-90	8.8	3.6	43	34	370	20	40	0.76	L1.0	0.008
		29-Aug-90	10.6	2.6	44	46	400	28	45	1.11	L1	0.007
		10-Oct-90	11	1.4	39	6	394	6.2	38	0.94	L1	0.008
GRATTAN CREEK NEAR MOUTH	00AL05FE0175	10-Apr-90	6.4									
		29-May-90	3.7	3.5	135	10	1378	6.8	369	5.63	L1.0	0.044
		30-Aug-90	9.2									
BATTLE RIVER (SITE 11) D/S HARDISTY	00AL05FB0500	03-May-89	10.5	7.6	68	235	626		52	1.02	0.1	0.01
		31-May-89	8.9	3.6	49	10	406		41	0.72	1	0.011
		27-Jun-89	8.9	1.6	36	8	388		31	0.63	L1.0	0.013
		26-Jul-89	9.3	2.1	35	18	440		36	0.77	1	0.007
		22-Aug-89	11.1	0.6	29	3.8	584		30	0.9	L1	L.001
		28-Sep-89	11.2	1.3	34	6	584		18	0.45	L1.0	0.005
		24-Oct-89	12.7	2	63	15	616		19	0.42	L1.0	0.004
		10-Jan-90	5.4		50						1.5	0.007
		10-Apr-90	10.1	5.8	67	486	966	240	42	1.04	L1.0	0.009
		28-May-90	8.8	3.4	40	35	388	20	37	0.7	L1.0	0.008
		29-Aug-90	10.1	4.5	48	55	422	34	42	1.08	L1	0.007
		10-Oct-90	10.9	1.4	39	12	422	7.6	33	0.92	L1	0.007
IRON CREEK	00AL05FB0700	10-Apr-90	10.8	4.3	54	79	474	42	135	2.06	L1.0	0.026

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE	DO	BOD	COD	NFR	FR	TURB.	COLOUR TRUE	TAN.& LIGN.	OIL GREASE	PHENOL-IC MAT.
		D/M/Y	mg/L 08102F	mg/L 08202L	mg/L 08304L	mg/L 10401L	mg/L 10451L	NTU 02074L	RCU 02024L	mg/L 06551L	mg/L 06524L	mg/L 06537L
NEAR HARDISTY		28-May-90	9.4	3.7	59	6	804	6.9	66	0.88	L1.0	0.013
		29-Aug-90	8.3	2.7	81	15	1216	10.9	51	1.66	0.2	0.017
		10-Oct-90	6.5	3.7	98	12	1370	9.4	106	2.03	L.1	0.018
BATTLE RIVER (SITE 12)	00AL05FE0400	04-May-89	9.4	7.6	66	226	818		51	1	0.3	0.011
AT HWY 41		31-May-89	9.8	3.7	49	24	454		38	0.71	L1.0	0.011
		27-Jun-89	10.5	2.2	34	7	434		30	0.58	1	0.008
		26-Jul-89	11	2.6	30	14	438		41	0.9	L1.0	0.007
		22-Aug-89	12.5	0.8	20	3	681		30	0.9	L.1	L.001
		28-Sep-89	11.9	1.1	30	9	588		17	0.38	1.4	0.005
		24-Oct-89	12.7	1.4	21	15	608		13	0.33	L1.0	0.003
		11-Jan-90	4	1.6	35	6	724		29	0.73	L1.0	0.005
		10-Apr-90	10.2	5.7	78	502	868	280	39	1.09	L1.0	0.01
		29-May-90	8.3	3.4	36	26	412	16.1	34	0.64	L1.0	0.008
		30-Aug-90	8.6	2.3	40	55	432	28	43	1.08	L.1	0.007
		11-Oct-90	11.3	1.4	32	8	458	6.9	30	0.49	L.1	0.006
BUFFALO CREEK	00AL05FE0500	10-Apr-90	11.8									
AT HWY 41		29-May-90	6.2	2.3	52	9	1172	6.1	92	1.03	1.4	0.016
		30-Aug-90	4.8									
		11-Oct-90	10.4									
GRIZZLY BEAR CREEK	00AL05FE0600	10-Apr-90	12.3									
NEAR MOUTH		29-May-90	8.1	4.1	112	11	1768	10.1	130	1.85	L1.0	0.022
		30-Aug-90	12.8									
BATTLE RIVER (SITE 13)	00AL05FE0850	04-May-89	9.8	7.8	87	254	1144		48	0.93	L.1	0.011
AT HWY 897		31-May-89	9.5	3.5	50	45	526		39	0.78	L1.0	0.011
		27-Jun-89	9.4	3	30	15	468		29	0.57	1	0.009
		26-Jul-89	10.7	1.6	30	12	440		50	0.84	1	0.007
		22-Aug-89	11.3	0.6	39	6.5	758		40	1	L.1	0.001
		28-Sep-89	9.5	1.9	36	61	718		23	0.46	L1.0	0.005
		24-Oct-89	12.1	1.4	21	16	682		20	0.39	L1.0	0.004
		11-Jan-90	1.9	1.1	33	9	826		32	0.38	L1.0	0.004
		10-Apr-90	10	4.4	113	1254	1498	355	49	1.17	L1.0	0.01
		29-May-90	8.5	3	39	36	444	21	36	0.66	L1.0	0.008
		30-Aug-90	8.6	3.1	47	79	468	45	42	1.12	0.2	0.007
		11-Oct-90	11.7	2.1	34	13	542	10	28	0.82	0.1	0.006
RIBSTONE CREEK	00AL05FE0875	10-Apr-90	12.5	3.1	25	22	335	17	40	0.77	L1.0	0.013
AT HWY 14		29-May-90	8.2	2.1	54	16	482	9	64	0.96	L1.0	0.014
		30-Aug-90	9.2	1.2	64	12	508	9.2	81	2.08	L.1	0.015
		11-Oct-90	10.2	1.9	61	11	644	9	62	1.14	L.1	0.01
BLACKFOOT CREEK	00AL05FE0890	10-Apr-90	12.4									
AT UNWIN ROAD		29-May-90	10.3	3.7	52	12	1288	8.1	56	0.7	L1.0	0.012

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE	DO	BOD	COD	NFR	FR	TURB.	COLOUR TRUE	TAN.& LIGN.	OIL GREASE	PHENOL-IC MAT.
		D/M/Y	mg/L 08102F	mg/L 08202L	mg/L 08304L	mg/L 10401L	mg/L 10451L	NTU 02074L	RCU 02024L	mg/L 06551L	mg/L 06524L	mg/L 06537L
BATTLE RIVER (SITE 14) AT UNWIN	00SA05FE1000	04-May-89	9.5	7.5	75	328	998		48	0.89	0.1	0.01
		30-May-89	9.3	3.4	54	32	556		41	0.82	1	0.011
		28-Jun-89	8.7	2.7	40	34	536		34	0.74	2	0.009
		03-Aug-89	9.3	2	34	33	502		41	0.42	L1.0	0.013
		22-Aug-89	8.9	0.7	39	14.9	785		40	1	L.1	L.001
		26-Sep-89	10.3	1.3	27	9	702		28	0.54	L1.0	0.006
		24-Oct-89	11.4	2	26	21	776		20	0.5	L1.0	0.004
		11-Jan-90	0	1.2	33	8	854		29	0.32	L1.0	0.004
		08-Feb-90	0									
		10-Apr-90	9.6	7.2	95	1060	1602	420	41	1.24	L1.0	0.01
		29-May-90	8.7	3.1	42	52	470	28	40	0.75	L1.0	0.007
		30-Aug-90	8.7	3	45	81	472	49	43	1.27	0.1	0.007
		11-Oct-90	11.9	2.5	31	20	562	12.8	25	0.42	L.1	0.005
BATTLE RIVER (SITE 15) AT HWY 40 NEAR MOUTH	00SA05FF1000	04-May-89	9.9	5.6	82	304	950		48	0.85	L.1	0.01
		30-May-89	9.4	3.3	50	80	624		39	0.76	1	0.009
		28-Jun-89	9.2	2.4	32	21	520		32	0.69	L1.0	0.007
		03-Aug-89	8.7	1.7	29	7	456		31	0.45	L1.0	0.012
		22-Aug-89	10.4	0.8	20	4.8	628		30	0.6	L.1	L.001
		26-Sep-89	11	L.20	27	3	640		23	0.46	L1.0	0.004
		24-Oct-89	11.6	1.6	23	22	712		16	0.35	L1.0	0.003
		11-Jan-90	0	1.2	22	3	1000		18	0.29	L1.0	0.002
		08-Feb-90	0.4	1.2	43	33	1010		33	0.4	L1.0	0.008
		10-Apr-90	10.5	7.3	142	1340	1626	520	43	1.11	L1.0	0.011

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE	DISS. C	PART. C	PART. P	TOTAL P	DISS. N-NH3	N-NO3 NO2	N-NO2	N-DISS. KJELD-N	N-PART. KJELD-N	TKN	N-PART TOTAL	PLANK. CHL-a	TOTAL COLIF.	FECAL COLIF.
		D/M/Y	mg/L 06107L	mg/L 06905L	mg/L 15901L	mg/L 15421L	mg/L 07562L	mg/L 07105L	mg/L 07205L	mg/L 07017L	mg/L 07920L	mg/L 07021L	mg/L 07906L	mg/m3 06715L	#/100mL 36001L	#/100mL 36011L
PIGEON LAKE CREEK NEAR HWY 611	00AL05FA0225	03-Apr-90														
		22-May-90	7	2.52	0.07	0.08	0.02	0.002	0.001	0.47	0.33	0.8	0.3	9.3	490	68
		28-Aug-90														
		09-Oct-90														
BATTLE RIVER (SITE 1) AT HWY 611	00AL05FA0250	02-May-89	10.3		0.04	0.07	0.019	0.013	0.002	0.54	0.23	0.77		8.9	72	L4.
		30-May-89	10.1		0.04	0.057	0.007	0.001	0.001	0.55	0.18	0.73		14.1	140	4
		26-Jun-89	10.3		0.03	0.088	0.018	0.001	0.001	0.56	0.08	0.64		5.4	64	16
		25-Jul-89	11.1		0.05	0.124	0.012	0.003	0.002	0.57	0.21	0.78		13.7	76	24
		23-Aug-89	13.1		0.02	0.072		0.08	0.01	0.56		0.7		1.2	80	36
		27-Sep-89	11.6	1.7	0.04	0.082	0.143	0.206	0.032	0.83	0.2	1.03	0.15	13.6	140	8
		24-Oct-89	10.6	0.43	0.02	0.054	0.057	0.27	0.011	0.63	0.12	0.75	0.05	4.7		20
		09-Jan-90	9.2	0.41	0.02	0.044	0.092	0.27	0.005	0.65	0.07	0.72	0.07	1.3	20	L4.
		07-Feb-90	9.7	0.48	0.02	0.042	0.112	0.32	0.004	0.75	0.03	0.78	0.06	1.3	48	4
		03-Apr-90	11.2	2.82	0.11	0.23	0.156	0.085	0.005	0.94	0.55	1.49	0.42	6	6100	12
		22-May-90	10.4	1.4	0.03	0.066	0.064	0.017	0.002	0.61	0.14	0.75	0.22	7.3	176	172
		28-Aug-90	9.7	0.57	0.02	0.047	0.03	0.161	0.018	0.57	0.12	0.69	0.08	2.8	160	8
		09-Oct-90	10.8	2.18	0.06	0.083	0.005	0.001	L.001	0.57	0.36	0.93	0.38	29.2	210	8
BATTLE RIVER (SITE 2) AT HWY 53	00AL05FA0280	02-May-89	15.1		0.08	0.153	0.024	0.006	0.003	0.87	0.33	1.19		3.6	2100	184
		30-May-89	14.5		0.05	0.103	0.026	0.012	0.003	0.77	0.18	0.95		12.8	800	116
		26-Jun-89	12.9		0.06	0.183	0.023	0.034	0.004	0.76	0.14	0.9		4.5	236	108
		25-Jul-89	14.9		0.04	0.237	0.015	0.003	0.002	0.75	0.17	0.91		2.3	184	132
		23-Aug-89	14		0.02	0.153		0.01	0.003	0.72		0.76		1.5	80	68
		27-Sep-89	12.7	1.76	0.06	0.134	0.013	0.008	0.001	0.65	0.25	0.9	0.18	29.1	68	4
		24-Oct-89	10.5	0.14	0.03	0.08	0.05	0.197	0.012	0.61	0.08	0.69	0.02	2.7	60	4
		09-Jan-90	10	0.34	0.06	0.12	0.31	0.22	0.004	0.89	0.1	0.99	0.22	0.4	68	8
		06-Feb-90	9.2	0.58	0.16	0.201	0.43	0.006	0.004	0.93	0.11	1.04	0.06	0.5	108	4
		03-Apr-90	15.9	4.62	0.2	0.385	0.32	0.129	0.013	1.55	1.75	3.3	0.64	5.7	4500	28
		22-May-90	10.4	0.77	0.04	0.106	0.038	0.018	0.003	0.69	0.11	0.8	0.12	5.2	2000	196
		28-Aug-90	7.6	0.67	0.03	0.057	0.02	0.069	0.007	0.55	0.14	0.69	0.1	5.4	330	84
		09-Oct-90	7.1	0.96	0.03	0.05	0.018	0.01	0.001	0.46	0.11	0.57	0.13	3.8	244	20
WOLF CREEK NEAR HWY 2	00AL05FA0287	03-Apr-90	17.6	1.38	0.09	0.355	0.5	0.8	0.058	2	0.85	2.85	0.26	8.2	7600	L4.
		22-May-90	16.6	1.63	1.76	2.05	0.022	0.003	0.002	0.96	0.31	1.27	0.27	34.1	48	8
		28-Aug-90	13.2	0.53	0.08	0.255	0.041	0.017	0.003	0.84	0.15	0.99	0.09	8.6	48	36
		09-Oct-90	12	1.52	0.1	0.169	0.006	0.002	0.001	0.73	0.27	1	0.29	27.2	240	L4.
BATTLE RIVER (SITE 3) NEAR HWY 2, APPROX. 8 KM D/S PONOKA	00AL05FA0413	02-May-89	17.3		0.13	0.395	0.239	0.186	0.027	1.37	0.59	1.96		87	280	12
		30-May-89	15.9		0.08	0.148	0.012	L.001	0.002	0.84	0.29	1.13		31.9	116	8
		26-Jun-89	13.3		0.05	0.262	0.018	0.005	0.002	0.75	0.17	0.91		14.1	24	8
		25-Jul-89	16		0.04	0.224	0.013	0.004	0.002	0.83	0.17	1		6	56	56
		23-Aug-89	17		0.04	0.17		L.01	0.002	0.78		1.04		16.1	132	76
		27-Sep-89	12.5	1.38	0.07	0.115	0.019	0.008	0.001	0.71	0.27	0.98	0.15	30.3	24	12
		24-Oct-89	10.9	0.68	0.05	0.102	0.016	0.001	0.001	0.6	0.2	0.8	0.16	13.7	64	16
		09-Jan-90	9.9	0.27	0.06	0.099	0.6	0.173	0.003	1.17	0.06	1.23	0.17	0.9	124	20
		03-Apr-90	15.2	3.63	0.17	0.365	0.41	0.3	0.022	1.67	0.58	2.25	0.49	4.3	4800	20

STATION	CODE	DATE	DISS. C	PART. C	PART. P	TOTAL P	DISS. N-NH3	N-NO3 NO2	N-NO2	N-DISS. KJELD-N	N-PART. KJELD-N	TKN	N-PART TOTAL	PLANK. CHL-a	TOTAL COLIF.	FECAL COLIF.
		D/M/Y	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/m3	#/100mL	#/100mL
			06107L	06905L	15901L	15421L	07562L	07105L	07205L	07017L	07920L	07021L	07906L	06715L	36001L	36011L
		22-May-90	12.3	1.45		0.34	0.23	0.13	0.044			1.46	0.24		190	10
		28-Aug-90	8.3	0.83	0.04	0.064	0.013	0.023	0.004	0.55	0.16	0.71	0.15	14.3	48	4
		09-Oct-90	7.7	0.69	0.03	0.066	0.033	0.038	0.004	0.54	0.12	0.66	0.1	8.3	225	36
BATTLE RIVER (SITE 4)	00AL05FA0500	02-May-89	18.7		0.11	0.16	0.013	0.002	0.002	1.18	0.61	1.79		47	76	L4.
D/S SAMSON LAKE		30-May-89	16.4		0.09	0.112	0.012	0.002	0.002	0.95	0.5	1.45		22.7	200	44
		26-Jun-89	16.1		0.06	0.084	0.022	0.002	0.001	0.91	0.41	1.32		25.2	32	32
		25-Jul-89	22.6		0.14	0.183	0.017	0.003	0.002	1.25	0.75	2		59.2	12	12
		23-Aug-89	27		0.23	0.28		L.01	0.002	1.8		4.12		137.5	10	4
		27-Sep-89	21.3	6.42	0.13	0.172	0.03	0.101	0.025	1.52	1.06	2.58	1.06	85.3	60	60
		24-Oct-89	18.1	6.09	0.14	0.171	0.038	0.053	0.008	1.1	1.2	2.3	0.71	97.8	80	4
		09-Jan-90	16.4	0.83	0.03	0.058	0.107	0.32	0.007	1.07	0.24	1.31	0.18	19.9	8	L4.
		03-Apr-90	13.8	6.04	0.17	0.38	0.48	0.4	0.022	1.73	0.47	2.2	0.77	15.9	8300	8
		22-May-90	14.8	5.55	0.13	0.162	0.028	0.003	0.001	0.88	0.77	1.65	0.75	34.2	130	10
		28-Aug-90	11.6	2.06	0.07	0.098	0.013	0.008	0.003	0.83	0.32	1.15	0.34	40.7	160	L4.
		09-Oct-90	10.7	1.89	0.05	0.072	0.046	0.064	0.01	0.81	0.25	1.06	0.26	21.4	64	L4.
PIPESTONE CREEK	00AL05FA0600	03-Apr-90	16.2	5.1	0.29	0.42	0.54	0.182	0.02	1.88	0.62	2.5	0.88	16	2900	28
AT HWY 822		22-May-90	16.8	1.66	0.07	0.156	0.034	0.116	0.003	1.18	0.29	1.47	0.29	21.2	60	4
		28-Aug-90	17.7	1.37	0.1	0.182	0.184	L.001	0.035	1.51	0.37	1.88	0.24	28.5	100	52
		09-Oct-90	18.2	2.8	0.11	0.142	0.011	0.001	0.001	1.23	0.42	1.65	0.44	35.4	222	L4.
BATTLE RIVER (SITE 5)	00AL05FA0700	02-May-89	17.4		0.2	0.245	0.013	0.002	0.002	1.15	0.91	2.06		60.6	250	L4.
AT HWY 21		30-May-89	16.3		0.12	0.15	0.014	0.002	0.002	1.02	0.54	1.56		27.6	24	20
		26-Jun-89	19.3		0.13	0.151	0.019	0.016	0.002	0.93	0.52	1.45		31		24
		25-Jul-89	21.5		0.12	0.166	0.013	0.008	0.002	1.02	0.38	1.4		25.4	300	180
		23-Aug-89	25.3		0.23	0.28		L.01	0.002	1.46		2.98		75.8	230	170
		27-Sep-89	19.4	3.38	0.09	0.126	0.03	0.012	0.002	1.18	0.55	1.73	0.46	28.8	40	40
		24-Oct-89	19.6	0.5	0.22	0.88	0.3	0.28	0.034	1.58	0.52	2.1	0.06	32.7	80	24
		09-Jan-90	16.3	0.77	0.04	0.069	0.54	0.42	0.005	1.54	0.14	1.68	0.1	2.3	20	L4.
		04-Apr-90	14	11.62	0.39	0.54	0.62	0.39	0.022	1.74	1.36	3.1	1.36	23	6200	124
		22-May-90	15.1	3.03	0.11	0.148	0.023	0.002	0.001	0.93	0.48	1.41	0.63	38.3	180	12
		28-Aug-90	13.2	2.34	0.08	0.114	0.02	0.002	0.001	0.86	0.37	1.23	0.37	46.9	16	L4.
		09-Oct-90	10.8	1.9	0.06	0.077	0.008	0.002	0.001	0.73	0.26	0.99	0.27	26.3	210	12
CAMROSE CREEK	00AL05FA0745	04-Apr-90	16.1	5.77	0.4	0.53	0.7	0.213	0.02	1.74	0.86	2.6	0.92	19.5	3400	108
NEAR MOUTH		22-May-90	20.6	3.79	0.26	0.445	0.58	1.08	0.158	2.35	0.7	3.05	0.67	81.2	340	8
		28-Aug-90	18.1	1.61	0.15	0.355	0.099	0.152	0.013	1.26	0.36	1.62	0.28	18.6	1800	148
		09-Oct-90	21	5.05	0.37	1.41	5.55	1.38	0.38	6.5	1	7.5	0.73	129.5		8
BATTLE RIVER (SITE 6)	00AL05FA0750	02-May-89	18		0.22	0.398	0.606	0.007	0.004	1.71	1.02	2.73		62.9	2500	36
D/S CAMROSE CREEK		30-May-89	16.8		0.11	0.135	0.02	0.002	0.002	0.99	0.46	1.45		28	44	32
U/S DRIEDMEAT L.		26-Jun-89	18.3		0.14	0.178	0.021	0.003	0.002	0.98	0.69	1.67		33.5	32	32
		25-Jul-89	19.7		0.1	0.184	0.021	0.003	0.002	1.16	0.33	1.49		31.6	72	48
		23-Aug-89	24.4		0.19	0.26		L.01	0.002	1.28		2.52		64.2	360	168
		27-Sep-89	21.5	3.1	0.11	0.18	0.025	0.002	0.001	1.35	0.65	2	0.44	33.9	160	12
		24-Oct-89	15.3	3.83	0.11	0.179	0.028	0.02	0.004	0.95	0.36	1.31	0.23	29	76	4
		09-Jan-90	16.8	0.51	0.05	0.079	0.75	0.37	0.005	1.8	0.18	1.98	0.09	2	56	L4.

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE	DISS. C	PART. C	PART. P	TOTAL P	DISS. N-NH3	N-NO3 NO2	N-NO2	N-DISS. KJELD-N	N-PART. KJELD-N	TKN	N-PART TOTAL	PLANK. CHL-a	TOTAL COLIF.	FECAL COLIF.
		D/M/Y	mg/L 06107L	mg/L 06905L	mg/L 15901L	mg/L 15421L	mg/L 07562L	mg/L 07105L	mg/L 07205L	mg/L 07017L	mg/L 07920L	mg/L 07021L	mg/L 07906L	mg/m3 06715L	#/100mL 36001L	#/100mL 36011L
		07-Feb-90	19.4	0.44	0.04	0.066	0.42	0.42	0.006	1.46	0.14	1.6	0.05	2.4	216	4
		04-Apr-90	14.9	9.91	0.49	0.59	0.57	0.46	0.023	1.61	2.29	3.9	1.23	18.9	4800	28
		22-May-90	15.3	3.48	0.14	0.178	0.026	0.002	0.001	0.95	0.71	1.66	0.62	55.3	148	20
		28-Aug-90	13.6	1.93	0.08	0.106	0.017	0.034	0.005	0.88	0.3	1.18	0.34	44.4	72	24
		09-Oct-90	12.1	2.3	0.1	0.22	0.56	0.195	0.04	1.41	0.42	1.83	0.41	48.7		12
BATTLE RIVER (SITE 7)	00AL05FA1000	03-May-89	19.8		0.25	0.422	0.034	0.24	0.024	1.22	1.36	2.58		109.7	180	L4.
AT HWY 850		30-May-89	15.8		0.16	0.21	0.014	0.001	0.002	1	0.72	1.72		27.3		4
D/S DRIEDMEAT L.		26-Jun-89	16.5		0.03	0.136	0.015	L.001	0.002	1.09	0.11	1.2		7.3	64	40
		25-Jul-89	19.4		0.09	0.412	0.019	0.007	0.002	1.01	0.31	1.32		8.1	780	780
		24-Aug-89	23.5		0.22	0.88		L.01	0.002	1.46		2.18		57.3	1300	24
		27-Sep-89	24.2	7.05	0.2	0.346	0.029	0.023	0.002	1.61	1.07	2.68	0.7	71.2	2700	72
		24-Oct-89	24.6	15.9	0.52	0.58	1.78	0.021	0.006	2.95	2.45	5.4	2.1	169.2	8000	40
		10-Jan-90	18	0.98	0.1	0.33	0.52	0.03	0.004	1.72	0.43	2.15	0.16	10.7	32	L4.
		04-Apr-90	16.7	3.62	0.16	0.38	0.51	0.203	0.016	1.64	0.46	2.1	0.58	27.7	2700	L4.
		28-May-90	14.6	2.04	0.07	0.152	0.027	0.002	0.002	1.02	0.41	1.43	0.29	13.6	180	L4.
		29-Aug-90	15	7.67	0.2	0.295	0.1	0.061	0.011	1.1	0.95	2.05	1.04	50.8	6600	64
		10-Oct-90	16.2	16.4	0.29	0.32	0.03	0.084	0.002	1.11	2.04	3.15	2.01	135	1900	100
MEETING CREEK	00AL05FC0290	05-Apr-90	14.9	7.29	0.31	0.46	0.42	0.64	0.039	1.41	0.84	2.25	0.82	4.2	2100	4
NEAR MOUTH		28-May-90	15.8	2.49	0.09	0.118	0.021	0.005	0.004	0.89	0.4	1.29	0.37	13.6		88
		29-Aug-90	16.9	1.53	0.08	0.127	0.082	0.013	0.003	1.06	0.31	1.37	0.29	6.5		L4.
		10-Oct-90	19.3	1.57	0.06	0.12	0.039	0.001	0.002	1.05	0.33	1.38	0.23	7.6	75	4
BIG KNIFE CREEK	00AL05FC0400	28-May-90	13.7	0.77	0.01	0.039	0.018	0.002	0.002	1.03	L.01	0.92	0.13	6.2		56
NEAR MOUTH																
BATTLE RIVER (SITE 8)	00AL05FC0660	03-May-89	16.3		0.18	0.259	0.034	0.26	0.024	1.03	1.03	2.06		124.9	64	4
IN BIG KNIFE PROV. P.		30-May-89	15.8		0.13	0.168	0.014	0.002	0.002	0.98	0.66	1.64		33.1	20	4
U/S FORESTBURG RES.		27-Jun-89	17		0.13	0.208	0.039	0.003	0.002	1.13	0.55	1.68		38		16
		26-Jul-89	18.2		0.11	0.175	0.033	0.006	0.002	0.95	0.51	1.46		23.6		4
		24-Aug-89	16.4		0.15	0.26		L.01	0.001	0.94		1.74		75.9		8
		28-Sep-89	18.1	2.94	0.02	0.107	0.025	0.003	0.002	1.23	0.54	1.77	0.47	55.5		
		24-Oct-89	18.8	3.13	0.13	0.22	0.086	0.26	0.05	1.31	0.67	1.98	0.47	63.8		36
		10-Jan-90	20.1	0.55	0.05	0.121	0.52	0.059	0.004	1.72	0.2	1.92	0.15	3.6	16	L4.
		05-Apr-90	15.2	7.82	0.22	0.27	0.48	0.174	0.015	1.46	0.64	2.1	0.85	28.8	340	4
		28-May-90	15.2	3.85	0.13	0.142	0.048	0.002	0.001	0.7	0.98	1.68	0.66	47.6		8
		29-Aug-90	15.5	2.65	0.1	0.137	0.018	0.007	0.004	1	0.56	1.56	0.52	102.8		L4.
		10-Oct-90	16.1	3.55	0.09	0.118	0.031	0.002	0.001	1.15	0.95	2.1	0.43	47.9	360	8
BATTLE RIVER (SITE 9)	00AL05FC0680	03-May-89	17.1		0.2	0.305	0.245	0.56	0.083	1.29	1	2.29		86.5	160	4
AT HWY 861		31-May-89	14.3		0.09	0.146	0.015	0.002	0.002	0.93	0.42	1.35		25.8	48	40
D/S FORESTBURG RES.		27-Jun-89	14.5		0.14	0.265	0.022	0.021	0.004	0.96	0.55	1.51		22.7		144
		26-Jul-89	15.7		0.1	0.167	0.045	0.021	0.003	0.93	0.31	1.24		11.6		40
		24-Aug-89	16.8		0.04	0.07		0.03	0.004	0.78		1.26		13.1		20
		28-Sep-89	16.4	0.83	0.1	0.133	0.016	0.003	0.001	0.97	0.54	1.51	0.09	20.1	48	20
		24-Oct-89	15.7	1.51	0.08	0.11	0.062	0.007	0.003	0.91	0.39	1.3	0.12	10	40	16

STATION	CODE	DATE	DISS. C	PART. C	PART. P	TOTAL P	DISS. N-NH3	N-NO3+ N02	N-NO2	N-DISS. KJELD-N	N-PART. KJELD-N	TKN	N-PART TOTAL	PLANK. CHL-a	TOTAL COLIF.	FECAL COLIF.
		D/M/Y	mg/L 06107L	mg/L 06905L	mg/L 15901L	mg/L 15421L	mg/L 07562L	mg/L 07105L	mg/L 07205L	mg/L 07017L	mg/L 07920L	mg/L 07021L	mg/L 07906L	mg/m3 06715L	#/100mL 36001L	#/100mL 36011L
		10-Jan-90	19	0.72	0.04	0.085	0.23	1.02	0.008	1.54	0.25	1.79	0.15	6.8	36	12
		05-Apr-90	16.1	6.82	0.43	0.51	0.38	0.27	0.02	1.15	1.15	2.3	1.25	19.5	1800	L10.
		28-May-90	16.1	4.47	0.07	0.1	0.02	0.002	0.002	0.97	0.39	1.36	0.56	21.6		20
		29-Aug-90	15.1	1.87	0.09	0.132	0.019	0.2	0.01	0.99	0.38	1.37	0.33	42.2		16
		10-Oct-90	15.4	0.58	0.03	0.057	0.029	0.112	0.014	1.04	0.17	1.21	0.1	13.2	120	48
PAINTEARTH CREEK AT MOUTH	00AL05FC0690	05-Apr-90	17.5	4.86	0.26	0.365	0.196	0.075	0.014	1.06	0.74	1.8	0.7	3.8	2000	30
		28-May-90	12.6	1.82	0.09	0.11	0.019	0.023	0.002	0.69	0.51	1.2	0.32	15.3		72
		29-Aug-90	13.1	1.67	0.07	0.084	0.011	0.003	0.001	0.71	0.37	1.08	0.33	19.7	2600	8
CASTOR CREEK NEAR MOUTH	00AL05FC0800	05-Apr-90														
		28-May-90	13.4	0.79	0.03	0.047	0.018	0.004	0.001	0.7	0.16	0.86	0.14	6.9	250	16
		29-Aug-90														
BATTLE RIVER (SITE 10) AT HWY 872	00AL05FC1000	03-May-89	17.7		0.29	0.339	0.027	0.58	0.05	1.02	1.36	2.38		115.6		L4.
		31-May-89	15		0.1	0.144	0.016	0.003	0.002	0.85	0.47	1.32		15.5	16	8
		27-Jun-89	14.4		0.05	0.084	0.033	L.001	0.001	0.86	0.27	1.13		7.1	190	136
		26-Jul-89	15		0.07	0.106	0.042	0.008	0.002	0.79	0.37	1.16		6.8		40
		22-Aug-89	14.3		0.01	0.03		0.01	0.002	0.76		0.9		2.9		48
		28-Sep-89	11.7	L.02	0.02	0.034	0.01	0.001	0.001	0.65	0.16	0.82	L.02	2.5	28	8
		24-Oct-89	11.7	0.44	0.02	0.031	0.018	0.002	0.001	0.64	0.1	0.74	0.03	3.1		4
		10-Jan-90	19.4	1.07	0.05	0.079	0.2	0.92	0.011	1.45	0.35	1.8	0.26	3	16	16
		07-Feb-90	21	0.76	0.04	0.066	0.126	1.21	0.014	1.49	0.23	1.72	0.09	1.5	108	48
		05-Apr-90	17.5	11.58	0.61	0.7	0.36	0.3	0.022	1.21	1.54	2.75	1.17	13.9	710	20
		28-May-90	13.1	2.92	0.07	0.094	0.046	0.002	0.001	0.91	0.35	1.26	0.31	11.8		16
		29-Aug-90	14.3	2.42	0.09	0.107	0.016	0.015	0.005	0.95	0.4	1.35	0.29	58.1		24
		10-Oct-90	14.5	0.26	0.01	0.032	0.027	0.011	0.003	0.96	0.09	1.05	0.08	1.9	108	12
BATTLE RIVER (SITE 11) D/S HARDISTY	00AL05FB0500	03-May-89	17.3		0.31	0.344	0.02	0.47	0.024	0.97	1.51	2.48		125.8	180	L4.
		31-May-89	14.7		0.11	0.139	0.016	0.001	0.002	0.81	0.52	1.33		13.4	8	4
		27-Jun-89	13		0.05	0.068	0.016	L.001	0.001	0.86	0.2	1.05		6.3	150	68
		26-Jul-89	14.4		0.08	0.101	0.035	0.009	0.001	0.77	0.39	1.15		8	120	120
		22-Aug-89	13.7		0.01	0.026		L.01	0.002	0.64		0.8		1.7		80
		28-Sep-89	9.6	0.05	0.02	0.029	0.008	0.002	0.001	0.54	0.08	0.62	L.02	2.3	28	20
		24-Oct-89	9.7	7.54	0.02	0.028	0.009	0.004	0.001	0.47	0.08	0.55	0.07	4.2	44	8
		10-Jan-90	18.8	0.85	0.04	0.063	0.35	0.7	0.01	1.71	0.29	2	0.13	2.3	60	L4.
		10-Apr-90	14.5	9.62	0.48	0.52	0.4	0.28	0.016	1.27	1.38	2.65	1.02	19.3		8
		28-May-90	12.5	3.1	0.07	0.089	0.018	0.012	0.001	0.83	0.33	1.16	0.32	9.3	400	148
		29-Aug-90	14.2	3.56	0.1	0.121	0.022	0.002	0.002	0.89	0.46	1.35	0.4	46.7		8
		10-Oct-90	14	0.74	0.03	0.04	0.021	0.018	0.002	0.19	1.56	1.75	0.13	9.9	66	20
IRON CREEK NEAR HARDISTY	00AL05FB0700	10-Apr-90	16.3	3.24	0.17	0.34	0.099	0.026	0.007	1.28	0.7	1.98	0.41	8.3	560	36
		28-May-90	20.6	2.34	0.11	0.307	0.058	0.01	0.005	1.38	0.38	1.76	0.33	17.3		136
		29-Aug-90	30.5	2.26	0.1	0.495	0.027	0.036	0.004	2.05	0.2	2.25	0.38	23.3	1900	12
		10-Oct-90	35	2.58	0.09	0.35	0.052	0.002	0.003	2.25	0.5	2.75	0.41	32.9	132	8
GRATTAN CREEK	00AL05FE0175	29-May-90	50	1.13	0.04	0.268	0.46	0.006	0.001	3.3	0.3	3.6	0.17	8.2		56

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE	DISS. C	PART. C	PART. P	TOTAL P	DISS. N-NH3	N-NO3 NO2	N-NO2	N-DISS. KJELD-N	N-PART. KJELD-N	TKN	N-PART TOTAL	PLANK. CHL-a	TOTAL COLIF.	FECAL COLIF.
		D/M/Y	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/m3	#/100mL	#/100mL
			06107L	06905L	15901L	15421L	07562L	07105L	07205L	07017L	07920L	07021L	07906L	06715L	36001L	36011L
NEAR MOUTH																
BATTLE RIVER	00AL05FE0400	04-May-89	16.6		0.31	0.353	0.051	0.48	0.018	1	1.4	2.4		109.6	100	4
AT HWY 41		31-May-89	14.5		0.1	0.14	0.014	0.001	0.002	0.84	0.43	1.27		15	136	4
		27-Jun-89	12.3		0.06	0.085	0.013	L.001	0.001	0.74	0.3	1.04		10.2	220	56
		26-Jul-89	14		0.08	0.114	0.055	0.024	0.002	0.73	0.35	1.08		11.8		100
		22-Aug-89	12.2		0.02	0.049		L.01	0.001	0.66		0.66		2.2		28
		28-Sep-89	8.4	L.02	0.01	0.031	0.01	0.002	0.001	0.46	0.06	0.52	L.02	1.4	80	20
		24-Oct-89	7.2	0.92	0.02	0.052	0.026	0.001	0.001	0.34	0.08	0.42	0.07	1.6	24	12
		11-Jan-90	14.9	0.35	0.03	0.076	0.38	0.46	0.014	1.39	0.08	1.47	0.07	2	32	L4.
		10-Apr-90	14.5	9.81	0.51	0.56	0.36	0.24	0.012	1.15	1.35	2.5	1.15	17.3		L10.
		29-May-90	13.2	2.44	0.07	0.093	0.062	0.003	0.001	0.77	0.36	1.13	0.31	3.5	135	80
		30-Aug-90	13.7	2.41	0.09	0.101	0.016	0.003	0.001	0.82	0.3	1.12	0.28	15.8	50	20
		11-Oct-90	11.7	0.8	0.02	0.036	0.011	0.006	0.001	0.71	0.1	0.81	0.11	6.7	66	28
BUFFALO CREEK	00AL05FE0500	10-Apr-90														
AT HWY 41		29-May-90	19.4	1.27	0.03	0.203	0.057	0.009	0.003	1.22	0.08	1.3	0.08	1.8	150	112
		30-Aug-90														
		11-Oct-90														
GRIZZLY BEAR CREEK	00AL05FE0600	10-Apr-90														
NEAR MOUTH		29-May-90	40.5	2.86	0.1	0.317	0.055	0.003	0.002	2.2	0.45	2.65	0.28	18.6	270	208
		30-Aug-90														
BATTLE RIVER (SITE 13)	00AL05FE0850	04-May-89	18.2		0.33	0.368	0.031	0.33	0.018	1	1.6	2.6		107.9	190	8
AT HWY 897		31-May-89	15.3		0.12	0.143	0.015	0.006	0.002	0.8	0.5	1.3		14.3	104	L4.
		27-Jun-89	13.2		0.07	0.084	0.013	L.001	0.001	0.72	0.27	0.98		9.3	360	52
		26-Jul-89	12.9		0.04	0.057	0.027	0.011	0.002	0.64	0.25	0.89		4.6	60	20
		22-Aug-89	14.2		0.02	0.036		L.01	0.002	0.72		0.88		2.4	210	128
		28-Sep-89	9.9	1.29	0.06	0.067	0.044	0.005	0.002	0.58	0.26	0.84	0.05	3.6	160	88
		24-Oct-89	8	0.42	0.01	0.025	0.017	0.004	0.001	0.46	0.02	0.48	0.05	12.5	16	L4.
		11-Jan-90	14	0.29	0.02	0.049	0.38	0.32	0.01	1.27	0.1	1.37	0.09	2.5	4	L4.
		10-Apr-90	14.7	12.85	0.69	0.75	0.36	0.24	0.012	1.2	1.7	2.9	1.4	15.1		L10.
		29-May-90	13.2	2.83	0.09	0.107	0.044	0.002	0.001	0.78	0.4	1.18	0.34	11.3	69	4
		30-Aug-90	13.4	3.1	0.18	0.197	0.014	0.001	0.001	0.84	0.45	1.29	0.35	20.7	30	16
		11-Oct-90	11.1	1.14	0.04	0.042	0.011	L.001	0.001	0.63		0.8	0.15	15.4	108	40
RIBSTONE CREEK	00AL05FE0875	10-Apr-90	9.9	1.11	0.07	0.125	0.106	0.014	0.002	0.74	0.25	0.99	0.16	8	108	L4.
AT HWY 14		29-May-90	20.3	0.55	0.03	0.101	0.04	0.004	0.001	1.11	0.15	1.26	0.07	2.5	280	120
		30-Aug-90	24.6	0.56	0.03	0.078	0.021	0.003	0.001	1.4	0.14	1.54	0.08	1.2	140	L4.
		11-Oct-90	22.3	0.87	0.04	0.07	0.017	0.001	0.001	1.25	0.16	1.41	0.11	5.1	132	4
BLACKFOOT CREEK	00AL05FE0890	10-Apr-90														
NEAR UNWIN		29-May-90	17.2	2.02	0.07	0.179	0.042	0.006	0.001	1.09	0.3	1.39	0.24	9.4	3500	60
		30-Aug-90												15.4	60	16
BATTLE RIVER (SITE 14)	00SA05FE1000	04-May-89	17.7		0.38	0.407	0.042	0.33	0.016	0.88	1.88	2.75		100.1	170	4

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE	DISS. C	PART. C	PART. P	TOTAL P	DISS. N-NH3	N-NO3 NO2	N-NO2	N-DISS. KJELD-N	N-PART. KJELD-N	TKN	N-PART TOTAL	PLANK. CHL-a	TOTAL COLIF.	FECAL COLIF.
		D/M/Y	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/m3	#/100mL	#/100mL
			06107L	06905L	15901L	15421L	07562L	07105L	07205L	07017L	07920L	07021L	07906L	06715L	36001L	36011L
AT UNWIN		30-May-89	16.3		0.12	0.146	L.001	0.001	0.002	0.87	0.47	1.34		13.8	100	4
		28-Jun-89	14.5		0.1	0.118	0.015	L.001	0.001	0.8	0.36	1.15		8.9	70	36
		03-Aug-89	13.7	2.06	0.05	0.073	0.013	0.001	0.002	0.7	0.29	1	0.17	6.5	80	72
		22-Aug-89	14		0.04	0.053		L.01	0.001	0.68		1		9		64
		26-Sep-89	10	L.02	0.07	0.082	0.011	0.001	0.001	0.54	0.11	0.65	L.02	8.3	32	16
		24-Oct-89	9.6	1.01	0.02	0.032	0.018	0.003	0.001	0.57	0.04	0.61	0.06	1.8	260	260
		11-Jan-90	12.6	0.48	0.04	0.067	0.35	0.23	0.008	1.12	0.1	1.22	0.09	8.5	4	L4.
		09-Feb-90	14.6	0.45	0.03	0.045	0.51	0.084	0.084	1.34	0.17	1.51	0.12	0.8	208	56
		10-Apr-90	15.5	25.92	0.88	0.94	0.39	0.28	0.013	1.2	2.7	3.9	1.92	12.3		10
		29-May-90	13.7	1.38	0.09	0.115	0.06	0.003	0.001	0.73	0.4	1.13	0.15	9.6	104	40
		30-Aug-90	13.9	4.38	0.24	0.265	0.014	0.003	0.001	0.84	0.59	1.43	0.64	19.3		80
		11-Oct-90	10.7	1.91	0.05	0.052	0.01	L.001	0.001	0.58	0.17	0.75	0.29	17.9	56	32
BATTLE RIVER (SITE 15)	00SA05FF1000	04-May-89	18.7		0.39	0.417	0.042	0.086	0.008	1	1.9	2.9		92.7	210	4
NEAR MOUTH		30-May-89	14.9		0.14	0.162	L.001	0.002	0.002	0.77	0.58	1.35		22.4	10	4
AT HWY 40		28-Jun-89	14.2		0.07	0.086	0.016	0.002	0.001	0.69	0.33	1.02		10		196
		03-Aug-89	12.1	1.58	0.03	0.042	0.012	0.003	0.002	0.65	0.17	0.82	0.11	5.7	30	8
		22-Aug-89	12.8		0.02	0.03		L.01	0.001	0.72		0.88		4.6	32	20
		26-Sep-89	9	L.02	0.03	0.034	0.017	0.001	0.001	0.51	0.07	0.58	L.02	1.6	16	16
		24-Oct-89	8.4	0.26	0.01	0.017	0.016	0.003	0.001	0.43	0.06	0.49	0.04	2.1	20	8
		11-Jan-90	10.5	0.02	0.01	0.012	0.29	0.048	0.005	0.86	0.08	0.94	0.03	0.5	12	L4.
		08-Feb-90	15.7	0.25	0.02	0.027	0.58	0.022	0.012	1.44	0.11	1.55	0.04	0.6	128	L4.
		10-Apr-90	15.1	23.43	0.99	1.04	0.52	0.31	0.012	1.23	3.07	4.3	2.19	16.4		L10.

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE D/M/Y	Al Ext. 13030L	Al Diss. 13109L	As Total 33005L	As Diss. 33102L	Ba Total 56009L	Ba Diss. 56109L	Be Diss. 04103L	Cd Total 48009L	Cd Diss. 48109L	Co Total 27009L	Co Diss. 27109L	Cr Total 24009L	Cr Diss. 24109L	Cu Total 29009L	Cu Diss. 29109L	Pb Ext. 82301L	Pb Diss. 82103L	Hg Total 80015L	Mo Total 42009L
PIPESTONE CREEK AT HWY 822	00AL05FA0600	03-Apr-90	0.603		0.0021	0.0011	0.127	0.096	L.001	L.001	L.001	0.004	0.001	0.006	0.002	0.007	0.002	L.002	L.002	L.0001	0.004
		22-May-90	0.049		0.0016	0.0014	0.057	0.057	L.001	0.002	0.002	0.001	0.001	0.002	0.002	0.004	L.001	L.002	L.002	L.0001	0.001
		28-Aug-90	0.038	0.017	0.0027	0.002	0.078	0.085	L.001	0.002	0.002	0.001	0.002	0.003	0.003	0.002	0.003	L.002	L.002	L.0001	0.002
		09-Oct-90	0.052	L.002	0.0015	0.001	0.075	0.084	L.001	0.002	0.002	0.001	0.001	0.004	0.004	0.003	0.002	0.003	L.002	L.0001	L.001
PIGEON LAKE CREEK EAST OF HWY 611	00AL05FA0225	03-Apr-90																			
		22-May-90	0.111		0.0016	0.0009	0.116	0.111	L.001	0.001	0.001	0.001	L.001	0.004	0.002	0.002	L.001	L.002	L.002	L.0001	0.001
		28-Aug-90																			
		09-Oct-90																			
BATTLE RIVER (SITE 1) AT HWY 611	00AL05FA0250	02-May-89	0 036	L 002	0 0014	0 0009	0 056	0 056	L 001	L 001	L 001	0.002	0.002	0.004	0.003	0.001	0.002		0.011	L.0001	0.002
		30-May-89	0 045		0 0014		0 071		L 001	0 001		L.001		0.002		0.001		L.002		L.0001	L.001
		26-Jun-89	0 496	0 016	0 002	0 001	0 075	0 078	L 001	L 001	L 001	0.001	L.001	0.002	L.001	L.001	L.001	L.002	L.002	L.0001	L.001
		25-Jul-89	0 03	0 009	0 0024	0 0097	0 072	0 069	L 001	L 001	L 001	L.001	L.001	0.006	0.002	L.001	0.002	L.002	L.002	L.0001	0.002
		23-Aug-89	L 002		0 0016		0 066		L 001	L 001		L.001		0.002		0.001		L.002		L.0001	0.003
		27-Sep-89	L 002	L 002	0 0018	0 0014	0 067	0 067	L 001	0 002	0 003	0.001	L.001	0.002	0.001	L.001	L.001	L.002	L.002	L.0001	0.002
		24-Oct-89	0 029	0 015	0 0009	0 0007	0 068	0 068	L 001	0 001	0 001	L.001	L.001	0.001	L.001	0.001	0.003	L.002	L.002	L.0001	0.002
		09-Jan-90	0 036	0 006	0 0025	0 0012	0 076	0 079	L 001	0 002	0 001	L.001	L.001	0.001	0.001	0.001	0.001	L.002	L.002	L.0001	0.002
		07-Feb-90	0 032	0 015	0 0006	0 0006	0 08	0 083	L 001	L 001	L 001	L.001	L.001	0.002	0.001	0.002	0.001	L.002	L.002	L.0001	L.001
		03-Apr-90	0 138		0 0012	0 0008	0 07	0 077	L 001	L 001	L 001	L.001	L.001	0.002	0.002	0.002	0.001	L.002	L.002	L.0001	0.002
		22-May-90	0.05		0.0014	0.001	0.077	0.071	L.001	0.001	0.001	L.001	L.001	0.004	0.003	L.001	L.001	L.002	L.002	L.0001	0.001
		28-Aug-90	0.045	0.01	0.0015	0.0012	0.079	0.079	L.001	0.002	0.002	L.001	L.001	0.003	0.002	0.002	0.002	L.002	L.002	L.0001	0.002
		09-Oct-90	0.058	0.024	0.0011	0.0006	0.091	0.102	L.001	L.001	L.001	L.001	L.001	L.001	0.001	L.001	L.001	L.002	L.002	L.0001	L.001
BATTLE RIVER (SITE 2) AT HWY 53 U/S PONOKA	00AL05FA0280	02-May-89	0.03	L.002	0.0019	0.0016	0.075	0.07	L.001	0.001	L.001	0.003	0.001	0.004	0.003	0.002	0.002		0.005	L.0001	0.002
		30-May-89	0.099		0.002		0.083		L.001	0.001		L.001		0.003		0.002		L.002		L.0001	0.002
		26-Jun-89	0.018	0.032	0.002	0.002	0.082	0.04	L.001	L.001	L.001	0.002	L.001	0.001	L.001	0.003	L.001	L.002	L.002	L.0001	0.002
		25-Jul-89	0.04	0.014	0.0044	0.0028	0.066	0.063	L.001	L.001	0.002	L.001	L.001	0.002	0.002	0.002	0.002	L.002	L.002	L.0001	0.002
		23-Aug-89	L.002		0.0022		0.065		L.001	0.002		L.001		0.002		0.001		L.002		L.0001	0.003
		27-Sep-89	0.015	L.002	0.0022	0.0018	0.07	0.068	L.001	0.002	0.002	0.001	0.001	0.002	0.002	0.001	0.002	L.002	L.002	L.0001	0.002
		24-Oct-89	0.034	0.021	0.0012	0.0009	0.072	0.088	L.001	0.001	0.001	L.001	L.001	0.001	0.002	0.001	0.002	L.002	0.002	L.0001	0.001
		09-Jan-90	0.02	0.015	0.001	0.0007	0.082	0.08	L.001	0.002	0.002	L.001	0.015	0.002	0.002	0.001	0.001	L.002	L.002	L.0001	0.002
		06-Feb-90	0.026	0.009	0.0014	0.0008	0.094	0.096	L.001	L.001	L.001	L.001	L.001	0.002	0.001	0.001	0.001	L.002	L.002	L.0001	0.001
		03-Apr-90	0.267		0.0019	0.001	0.098	0.087	L.001	0.001	L.001	0.002	0.001	0.003	0.002	0.004	0.002	L.002	L.002	L.0001	0.003
		22-May-90	0.024		0.0017	0.0013	0.079	0.077	L.001	0.002	0.001	L.001	L.001	0.002	0.002	L.001	0.002	L.002	L.002	L.0001	0.001
		28-Aug-90	0.039	0.007	0.0015	0.0013	0.089	0.087	L.001	0.002	0.002	L.001	L.001	0.002	0.003	0.001	0.002	L.002	L.002	L.0001	0.002
		09-Oct-90	0.058	0.019	0.001	0.0008	0.091	0.105	L.001	0.001	0.001	L.001	0.001	0.003	0.003	0.001	0.003	L.002	L.002	L.0001	L.001
WOLF CREEK NEAR HWY 2	00AL05FA0287	03-Apr-90	0.047		0.0019	0.0021	0.08	0.082	L.001	0.001	L.001	L.001	L.001	0.002	0.002	0.002	0.002	L.002	L.002	L.0001	0.002
		22-May-90	0.013		0.0067	0.0051	0.087	0.084	L.001	0.002	0.002	0.001	0.002	0.004	0.004	0.001	0.002	L.002	L.002	L.0001	0.002
		28-Aug-90	0.016	0.01	0.004	0.0034	0.131	0.125	L.001	0.003	0.003	0.001	0.001	0.004	0.004	0.002	0.002	L.002	L.002	L.0001	0.002
		09-Oct-90	0.024	L.002	0.0025	0.0017	0.121	0.128	L.001	0.002	0.003	0.001	0.001	0.005	0.004	0.003	0.003	L.002	L.002	L.0001	0.001
BATTLE RIVER (SITE 3) NR HWY.2A, APPROX. 8 KM D/S PONOKA	00AL05FA0413	02-May-89	0.005	L.002	0.0028	0.0023	0.081	0.078	L.001	L.001	L.001	L.001	L.001	0.004	0.004	0.002	0.002		0.005	L.0001	0.001
		30-May-89	0.041		0.002		0.082		L.001	0.001		L.001		0.003		0.002		L.002		L.0001	0.002
		26-Jun-89	0.006		0.002		0.067		L.001	L.001		0.001		L.001		L.001		L.002		L.0001	0.001
		25-Jul-89	0.025	0.004	0.0033	0.0031	0.062	0.062	L.001	0.002	0.002	0.001	0.002	0.004	0.001	0.002	0.002	L.002	L.002	L.0001	0.003
		23-Aug-89	L.002		0.0027		0.066		L.001	0.002		L.001		0.002		0.001		L.002		L.0001	0.002
		27-Sep-89	0.008	L.002	0.0014	0.0013	0.064	0.065	L.001	0.001	0.002	0.001	L.001	0.002	0.002	0.002	0.002	L.002	L.002	L.0001	0.002
		24-Oct-89	0.03	L.002	0.0016	0.0008	0.068	0.076	L.001	0.001	0.001	L.001	L.001	0.001	0.002	0.001	0.001	0.002	L.002	L.0001	0.002
		09-Jan-90	0.011	0.062	0.0009	0.0005	0.083	0.082	L.001	0.001	L.001	L.001	L.001	0.003	0.002	0.001	L.001	L.002	L.002	L.0001	0.002
		03-Apr-90	0.233		0.002	0.0012	0.093	0.08	L.001	0.001	L.001	0.001	L.001	0.003	0.001	0.003	0.002	L.002	L.002	L.0001	0.002
		22-May-90	0.024	0.006	0.0018	0.0019	0.073	0.067	L.001	0.001	0.001	0.001			0.002	0.001	L.001	L.002	L.002	L.0001	0.001
		28-Aug-90	0.019	0.007	0.0014	0.0013	0.089	0.098	L.001	0.002	0.002	L.001	L.001	0.003	0.003	0.001	0.001	0.005	L.002	L.0001	L.001
		09-Oct-90	0.033	L.002	0.001	0.0009	0.086	0.092	L.001	0.001	0.002	L.001	L.001	0.003	0.003	0.002	0.003	L.002	L.002	L.0001	L.001
BATTLE RIVER (SITE 4) D/S SAMSON LAKE	00AL05FA0500	02-May-89	0.003	0.01	0.0018	0.0012	0.076	0.072	L.001	L.001	L.001	L.001	L.001	0.003	0.005	0.002	0.002		0.002	L.0001	0.002
		30-May-89	0.049		0.0019		0.087		L.001	0.002		0.001		0.003		0.002		L.002		L.0001	0.002
		26-Jun-89	0.011		0.001		0.071		L.001	L.001		0.001		L.001		L.001		L.002		L.0001	L.001
		25-Jul-89	0.025	0.009	0.0047	0.0036	0.039	0.041	L.001	L.001	0.001	L.001	0.001	0.002	0.001	0.001	0.002	L.002	L.002	L.0001	0.002
		23-Aug-89	L.002		0.0051		0.039		L.001	L.001		L.001		L.001		L.001		L.002		L.0001	0.003
		27-Sep-89	0.015	0.011	0.002	0.0017	0.042	0.042	L.001	0.002	0.002	L.001	L.001	0.002	0.001	0.001	0.002	L.002	L.002	L.0001	0.002
		24-Oct-89	0.026	0.021	0.0008	0.0013	0.055	0.055	L.001	0.001	0.001	0.001	0.001	0.001	0.001	L.001	0.002	L.002	0.003	L.0001	0.002
		09-Jan-90	0.015	0.019	0.0012	0.0012	0.101	0.101	L.001	0.003	0.002	L.001	0.003	0.002	0.003	0.001	0.001	L.002	L.002	L.0001	0.003
		03-Apr-90	0.145		0.0016	0.0012	0.076	0.072	L.001	L.001	0.001	0.001	L.001	0.002	0.001	0.003	0.002	L.002	L.002	L.0001	0.002
		22-May-90	0.043	0.01	0.0019	0.0012	0.075	0.067	L.001	0.002	0.002	L.001	0.002	0.003	0.003	L.001	L.001	L.002	0.004	L.0001	0.001
		28-Aug-90	0.022	0.014	0.0015	0.0015	0.086	0.081	L.001	0.002	0.002	L.001	L.001	0.002	0.003	0.001	0.003	L.002	L.002	L.0001	L.001
		09-Oct-90	0.052	0.01	0.0008	0.0007	0.08	0.088	L.001	0.002	0.001	L.001	L.001	0.003	0.003	0.001	L.001	L.002	L.002	L.0001	L.001

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE D/M/Y	Mo Diss. 42109L	Mn Total 25004L	Mn Diss. 25109L	Ni Total 28009L	Ni Diss. 28109L	Fe Total 26009L	Fe Diss. 26109L	Zn Total 30009L	V Total 23009L	V Diss. 23109L	Se Total 34005L	Se Diss. 34102L
PIPESTONE CREEK AT HWY 822	00AL05FA0600	03-Apr-90	0.002	0.37	0.262	0.01	0.006	5.384	0.695	0.021	0.01	0.002	0.0001	L.0001
		22-May-90	0.001	0.097	0.022	0.003	0.004	0.465	0.113	0.003	0.003	0.003	L.0001	L.0001
		28-Aug-90	0.001	0.248	0.144	0.005	0.007	0.894	0.23	0.003	0.004	0.003	0.0001	L.0001
		09-Oct-90	L.001	0.189	0.055	0.014	0.007	0.623	0.121	0.003	0.003	0.003	0.0001	0.0001
PIGEON LAKE CREEK EAST OF HWY 611	00AL05FA0225	03-Apr-90												
		22-May-90	0.001	0.067	0.002	0.004	0.002	1.701	0.081	0.008	0.005	0.003	L.0001	L.0001
		28-Aug-90												
		09-Oct-90												
BATTLE RIVER (SITE 1) AT HWY 611	00AL05FA0250	02-May-89	0.002	0.038	0.016	0.005	0.004	0.324	0.058	0.002	0.003	0.002	L.0001	L.0001
		30-May-89		0.054		0.003		0.232		L.001	0.003		L.0001	
		26-Jun-89	0.001	0.09	0.043	0.002	0.003	0.324	0.124	0.005	0.003	0.002	L.0001	L.0001
		25-Jul-89	0.002	0.095	0.004	0.002	0.002	0.291	0.083	0.003	0.003	0.003	L.0001	L.0001
		23-Aug-89		0.035		0.002		0.246		0.004	0.003		L.0001	
		27-Sep-89	L.001	0.088	0.056	L.001	0.003	0.337	0.161	L.001	0.002	0.003	L.0001	L.0001
		24-Oct-89	0.002	0.039	0.027	0.003	0.01	0.339	0.118	0.003	0.002	L.002	L.0001	L.0001
		09-Jan-90	0.002	0.057	0.049	0.003	0.004	0.262	0.062	0.002	L.002	0.002	L.0001	L.0001
		07-Feb-90	L.001	0.068	0.059	0.001	0.001	0.275	0.039	0.007	L.002	L.002	L.0001	L.0001
		03-Apr-90	L.001	0.197	0.152	0.003	0.002	0.965	0.177	0.007	0.003	0.002	0.0001	L.0001
		22-May-90	0.001	0.071	0.035	0.002	0.003	0.405	0.092	0.002	0.003	0.003	0.0002	L.0001
		28-Aug-90	0.002	0.038	0.005	0.003	0.003	0.294	0.097	0.002	0.003	0.003	0.0001	0.0001
		09-Oct-90	L.001	0.13	0.019	0.002	0.001	0.424	0.102	L.001	L.002	L.002	0.0001	0.0001
BATTLE RIVER (SITE 2) AT HWY 53 U/S PONOKA	00AL05FA0280	02-May-89	0.002	0.074	0.035	0.006	0.005	0.764	0.258	0.003	0.004	0.003	L.0001	L.0001
		30-May-89		0.065		0.005		0.709		L.001	0.004		L.0001	
		26-Jun-89	L.001	0.054	0.012	0.004	0.006	0.584	0.083	0.006	0.008	L.002	L.0001	L.0001
		25-Jul-89	0.002	0.027	0.004	0.002	0.002	0.294	0.059	0.004	0.003	0.003	L.0001	L.0001
		23-Aug-89		0.012		0.003		0.228		0.003	0.003		L.0001	
		27-Sep-89	0.002	0.026	0.003	0.003	0.004	0.376	0.114	0.001	0.004	0.003	L.0001	L.0001
		24-Oct-89	0.002	0.012	0.005	0.003	0.005	0.344	0.141	0.001	0.002	0.002	L.0001	L.0001
		09-Jan-90	0.002	0.076	0.072	0.004	0.004	0.575	0.135	0.001	0.003	0.002	0.0001	L.0001
		06-Feb-90	0.001	0.74	0.708	0.003	0.003	0.991	0.09	0.009	0.002	0.003	0.0001	L.0001
		03-Apr-90	0.001	0.199	0.128	0.005	0.004	2.425	0.343	0.012	0.005	0.002	0.0002	L.0001
		22-May-90	L.001	0.051	0.021	0.003	0.004	0.468	0.11	0.001	0.003	0.003	0.0001	L.0001
		28-Aug-90	0.003	0.042	0.01	0.003	0.005	0.38	0.07	0.002	0.003	0.003	L.0001	L.0001
		09-Oct-90	L.001	0.054	0.034	0.004	0.003	0.594	0.07	0.003	0.003	0.002	L.0001	L.0001
WOLF CREEK NEAR HWY 2	00AL05FA0287	03-Apr-90	0.002	0.124	0.106	0.004	0.004	0.593	0.289	0.004	0.003	0.003	0.0001	0.0002
		22-May-90	0.001	0.137	0.076	0.006	0.006	0.461	0.099	0.001	0.005	0.004	0.0001	0.0001
		28-Aug-90	0.002	0.156	0.116	0.005	0.006	0.364	0.081	0.001	0.005	0.005	0.0001	0.0001
		09-Oct-90	L.001	0.25	0.205	0.005	0.005	0.48	0.12	0.004	0.004	0.004	L.0001	L.0001
BATTLE RIVER (SITE 3) NR HWY.2A, APPROX. 8 KM D/S PONOKA	00AL05FA0413	02-May-89	0.001	0.074	0.027	0.006	0.006	0.688	0.286	0.01	0.003	0.003	L.0001	L.0001
		30-May-89		0.063		0.005		0.465		L.001	0.004		L.0001	
		26-Jun-89		0.031		0.004		0.179		0.003	0.003		L.0001	
		25-Jul-89	0.002	0.032	0.01	0.003	0.007	0.267	0.074	L.001	0.004	0.003	L.0001	L.0001
		23-Aug-89		0.038		0.004		0.198		0.003	0.003		L.0001	
		27-Sep-89	0.003	0.06	0.003	0.003	0.003	0.244	0.051	0.002	0.004	0.003	L.0001	L.0001
		24-Oct-89	0.002	0.029	0.003	0.004	0.004	0.379	0.136	0.001	0.002	L.002	L.0001	0.0001
		09-Jan-90	0.002	0.103	0.097	0.004	0.004	0.41	0.056	0.001	0.003	0.002	0.0001	L.0001
		03-Apr-90	0.002	0.206	0.142	0.005	0.003	2.038	0.421	0.008	0.004	L.002	0.0002	L.0001
		22-May-90	0.001	0.059	0.005	0.005	0.005	0.386	0.082	0.003	0.003	0.003	0.0001	L.0001
		28-Aug-90	L.001	0.043	0.002	0.003	0.003	0.219	0.089	L.001	0.003	0.003	0.0001	L.0001
		09-Oct-90	L.001	0.056	0.02	0.004	0.003	0.453	0.072	0.003	0.003	0.002	L.0001	L.0001
BATTLE RIVER (SITE 4) D/S SAMSON LAKE	00AL05FA0500	02-May-89	0.002	0.041	0.008	0.005	0.005	0.355	0.325	0.01	L.002	0.004	L.0001	L.0001
		30-May-89		0.04		0.005		0.354		L.001	0.004		L.0001	
		26-Jun-89		0.018		0.003		0.136		0.005	0.003		L.0001	
		25-Jul-89	0.002	0.049	0.005	0.002	0.007	0.245	0.033	0.003	0.005	0.004	L.0001	L.0001
		23-Aug-89		0.036		0.002		0.246		0.003	0.005		L.0001	
		27-Sep-89	0.002	0.049	0.005	0.003	0.005	0.189	0.046	0.002	0.003	0.003	L.0001	L.0001
		24-Oct-89	0.002	0.051	0.002	0.003	0.01	0.204	0.019	0.001	0.002	0.002	0.0001	0.0001
		09-Jan-90	0.002	0.037	0.032	0.007	0.004	0.15	0.038	L.001	0.003	0.003	L.0001	0.0001
		03-Apr-90	0.004	0.142	0.098	0.004	0.006	1.566	0.327	0.006	0.004	0.003	0.0001	L.0001
		22-May-90	0.002	0.052	0.002	0.005	0.007	0.317	0.033	0.001	0.004	0.003	L.0001	L.0001
		28-Aug-90	0.001	0.052	0.004	0.004	0.004	0.266	0.052	L.001	0.003	0.003	L.0001	L.0001
		09-Oct-90	L.001	0.027	0.006	0.003	0.003	0.275	0.066	0.002	0.002	0.002	L.0001	L.0001

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE D/M/Y	Al Ext. 13030L	Al Diss. 13109L	As Total 33005L	As Diss. 33102L	Ba Total 56009L	Ba Diss. 56109L	Be Diss. 04103L	Cd Total 48009L	Cd Diss. 48109L	Co Total 27009L	Co Diss. 27109L	Cr Total 24009L	Cr Diss. 24109L	Cu Total 29009L	Cu Diss. 29109L	Pb Ext. 82301L	Pb Diss. 82103L	Hg Total 80015L	Mo Total 42009L
BATTLE RIVER (SITE 5) AT HWY 21	00AL05FA0700	02-May-89	0.101	L.002	0.0031	0.0012	0.087	0.084	L.001	L.001	L.001	0.002	L.001	0.004	0.003	0.004	0.002		0.009	L.0001	0.004
		30-May-89	0.155		0.0024		0.093		L.001	0.002		0.001		0.004		0.002		L.002		L.0001	0.003
		26-Jun-89	0.05		0.002		0.077		L.001	L.001		0.001		L.001		0.001		L.002		L.0001	L.001
		25-Jul-89	0.083	0.004	0.0034	0.0028	0.062	0.146	L.001	0.001	0.001	0.002	L.001	0.002	0.002	0.002	0.002	L.002	L.002	L.0001	0.002
		23-Aug-89	0.022		0.0049		0.064		L.001	0.003		0.001		0.002		0.002		L.002		L.0001	0.004
		27-Sep-89	0.06	L.002	0.0027	0.0019	0.064	0.06	L.001	0.001	0.002	0.002	0.001	0.002	0.002	0.002	0.002	L.002	L.002	L.0001	0.003
		24-Oct-89	0.088	0.021	0.0029	0.0026	0.066	0.06	L.001	0.001	0.002	0.001	0.001	0.002	0.002	0.002	0.004	0.002	0.003	L.0001	0.003
		09-Jan-90	0.066	0.066	0.0011	0.0007	0.108	0.106	L.001	0.002	0.002	L.001	0.002	0.003	0.003	0.002	0.002	L.002	L.002	L.0001	0.002
		04-Apr-90	0.519		0.0028	0.001	0.144	0.074	L.001	0.001	0.001	0.004	L.001	0.008	0.001	0.009	0.002	L.002	0.006	L.0001	0.005
		22-May-90	0.066	0.01	0.0018	0.0013	0.07	0.067	L.001	0.002	0.002	0.002	0.003	0.003	0.002	L.001	L.001	L.002	L.002	L.0001	0.001
		28-Aug-90	0.059	0.017	0.0021	0.0013	0.097	0.089	L.001	0.002	0.002	0.001	0.001	0.003	0.003	0.002	0.003	L.002	L.002	L.0001	L.001
		09-Oct-90	0.058	L.002	0.0013	0.0006	0.088	0.1	L.001	0.002	0.002	0.001	0.001	0.003	0.003	0.002	0.001	L.002	L.002	L.0001	0.001
CAMROSE CREEK NEAR MOUTH	00AL05FA0745	04-Apr-90	0.206		0.0029	0.0014	0.084	0.05	L.001	0.001	0.001	0.004	0.002	0.005	0.002	0.006	0.002	0.006	0.002	L.0001	0.004
		22-May-90	0.116		0.0038	0.0018	0.054	0.044	L.001	0.002	0.003	0.003	0.003	0.005	0.004	0.002	L.001	L.002	L.002	L.0001	0.002
		28-Aug-90	0.091	0.02	0.0033	0.0024	0.054	0.042	L.001	0.003	0.003	0.002	0.002	0.005	0.004	0.004	0.003	0.002	L.002	L.0001	0.002
		09-Oct-90	0.169	L.002	0.0042	0.0038	0.044	0.059	L.001	0.004	0.004	0.003	0.003	0.007	0.005	0.006	0.003	L.002	L.002	0.0002	0.003
BATTLE RIVER (SITE 6) D/S CAMROSE CR.	00AL05FA0750	02-May-89	L.002	0.099	0.0032	0.0013	0.081	0.07	L.001	L.001	L.001	0.002	0.001	0.005	0.003	0.004	0.002		0.007	L.0001	0.002
		30-May-89	0.111		0.0027		0.09		L.001	0.002		0.001		0.003		0.003		0.002		L.0001	0.003
		26-Jun-89	0.002	0.018	0.002	0.001	0.075	0.072	L.001	L.001	L.001	0.001	L.001	0.001	L.001	0.001	0.002	L.002	L.002	L.0001	0.001
		25-Jul-89	0.051	0.004	0.0045	0.0035	0.058	0.058	L.001	0.002	0.002	0.001	0.001	0.002	0.002	0.002	0.002	L.002	L.002	L.0001	0.002
		23-Aug-89	L.002		0.0045		0.055		L.001	0.001		0.001		0.002		0.002		L.002		L.0001	0.002
		27-Sep-89	0.044	L.002	0.0043	0.003	0.061	0.058	L.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	L.002	L.002	L.0001	0.002
		24-Oct-89	0.083	0.019	0.0016	0.0013	0.073	0.069	L.001	0.002	L.001	0.001	0.001	0.002	0.002	0.002	0.002	L.002	L.002	L.0001	0.003
		09-Jan-90	0.015	0.015	0.0013	0.0007	0.114	0.111	L.001	0.002	0.002	0.002	0.003	0.003	0.002	0.002	0.002	L.002	L.002	L.0001	L.001
		07-Feb-90	0.021	0.003	0.0008	0.0005	0.127	0.135	L.001	0.002	0.001	0.001	0.002	0.002	0.003	0.002	0.002	L.002	L.002	L.0001	0.004
		04-Apr-90	0.367		0.0037	0.0009	0.148	0.075	L.001	0.001	0.001	0.005	0.001	0.008	0.002	0.009	0.002	0.004	L.002	L.0001	0.006
		22-May-90	0.056	0.006	0.0018	0.0014	0.069	0.065	L.001	0.002	0.003	0.002	0.002	0.003	0.003	L.001	L.001	L.002	L.002	L.0001	0.001
		28-Aug-90	0.046	0.017	0.0017	0.0013	0.096	0.098	L.001	0.002	0.002	0.001	0.001	0.004	0.003	0.002	0.002	L.002	L.002	L.0001	L.001
		09-Oct-90	0.058	L.002	0.0013	0.0009	0.079	0.09	L.001	0.002	0.002	0.001	0.002	0.004	0.003	0.003	0.003	L.002	L.002	0.0001	0.003
BATTLE RIVER (SITE 7) AT HWY 850	00AL05FA1000	03-May-89	0.076	0.046	0.0022	0.0018	0.07	0.069	L.001	0.001	0.001	L.001	0.001	0.001	L.001	0.003	0.005		0.004	L.0001	0.003
		30-May-89	0.031		0.0017		0.069		L.001	L.001		0.001		0.003		0.001		L.002		L.0001	0.002
		26-Jun-89	0.002		0.001		0.079		L.001	L.001		0.001		L.001		L.001		L.002		L.0001	0.001
		25-Jul-89	L.002	0.009	0.0032	0.0025	0.055	0.051	L.001	0.002	0.001	0.001	0.001	0.004	0.002	L.001	L.001	L.002	L.002	L.0001	L.001
		24-Aug-89	L.002		0.0051		0.046		L.001	0.001		L.001		0.002		0.001		L.002		L.0001	0.003
		27-Sep-89	0.02	L.002	0.0059	0.0048	0.059	0.054	L.001	0.002	0.003	0.002	0.002	0.003	0.002	0.002	0.002	L.002	L.002	L.0001	0.003
		24-Oct-89	0.246	0.032	0.0029	0.0006	0.151	0.149	L.001	0.001	0.002	0.003	0.001	0.004	0.002	0.007	0.002	0.005	L.002	L.0001	0.006
		10-Jan-90	0.031	0.014	0.0013	0.001	0.091	0.094	L.001	0.001	0.001	0.001	L.001	0.002	0.002	0.002	0.001	L.002	L.002	L.0001	0.002
		04-Apr-90	0.052		0.0017	0.0016	0.087	0.077	L.001	0.002	0.002	0.002	0.001	0.004	0.003	0.003	0.001	L.002	L.002	L.0001	0.003
		28-May-90	0.028	0.008	0.0015	0.0017	0.076	0.073	L.001	0.002	L.001	0.002	0.002	0.002	0.002	0.002	0.002	L.002	L.002	0.0001	0.002
		29-Aug-90	0.051	0.02	0.003	0.002	0.103	0.082	L.001	0.001	0.002	0.002	L.001	0.003	0.003	0.004	0.001	L.002	L.002	L.0001	0.003
		10-Oct-90	0.169	0.013	0.0016	0.0007	0.124	0.1	L.001	0.002	0.003	0.003	0.002	0.023	0.017	0.006	0.002	0.002	L.002	L.0001	0.003
MEETING CREEK NEAR MOUTH	00AL05FC0290	05-Apr-90	0.173		0.0035	0.0014	0.117	0.189	L.001	L.001	L.001	0.004	0.002	0.006	0.002	0.01	0.008	0.008	0.005	L.0001	0.005
		28-May-90	0.055		0.0024	0.0013	0.106	0.092	L.001	0.002	0.002	0.003	0.002	0.003	0.003	0.003	0.002	L.002	L.002	L.0001	0.004
		29-Aug-90	0.041	0.014	0.0027	0.0016	0.103	0.136	L.001	0.002	0.003	0.002	0.002	0.004	0.003	0.005	0.003	0.002	L.002	L.0001	0.004
		10-Oct-90	0.03	L.002	0.0018	0.0014	0.087	0.085	L.001	0.003	0.002	0.002	0.002	0.004	0.004	0.006	0.005	L.002	L.002	0.0002	0.003
BIG KNIFE CREEK NEAR MOUTH	00AL05FC0400	28-May-90	0.017		0.0011	0.0007	0.139	0.128	L.001	L.001	L.001	0.002	0.001	0.003	0.002	0.002	0.002	L.002	L.002	L.0001	0.002
BATTLE RIVER (SITE 8) BIG KNIFE PROV. PK U/S FORESTBURG	00AL05FC0660	03-May-89	0.086	0.051	0.0025	0.0013	0.071	0.073	L.001	L.001	0.002	0.001	0.001	0.004	0.003	0.003	0.002		0.003	L.0001	0.002
		30-May-89	0.035		0.002		0.068		L.001	0.001		0.001		0.004		0.002		L.002		L.0001	0.002
		27-Jun-89	0.044		0.003		0.083		L.001	L.001		0.001		L.001		0.001		L.002		L.0001	0.001
		26-Jul-89	0.128	0.014	0.0038	0.0024	0.089	0.11	L.001	0.001	0.002	0.002	0.002	0.002	0.001	0.003	0.003	L.002	L.002	L.0001	0.003
		24-Aug-89	0.01		0.0065		0.085		L.001	0.001		0.002		0.002		0.004		L.002		L.0001	0.003
		28-Sep-89	0.014	0.048	0.0053	0.0054	0.092	0.084	L.001	0.001	0.001	0.002	0.002	0.002	0.003	0.005	0.005	L.002	L.002	L.0001	0.004
		24-Oct-89	0.062	0.006	0.0064	0.0046	0.111	0.1	L.001	0.002	0.001	0.001	0.001	0.002	0.001	0.005	0.004	L.002	0.002	L.0001	0.004
		10-Jan-90	0.096	0.015	0.0014	0.0012	0.098	0.098	L.001	0.002	0.002	0.002	0.002	0.003	0.002	0.006	0.002	L.002	L.002	L.0001	0.002
		05-Apr-90	0.099		0.0037	0.0008	0.121	0.164	L.001	0.002	0.001	0.003	0.001	0.005	0.002	0.006	0.002	0.004	L.002	L.0001	0.003
		28-May-90	0.04	L.002	0.0018	0.0014	0.084	0.081	L.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	L.002	L.002	L.0001	0.002
		29-Aug-90	0.028	0.014	0.0022	0.0017	0.093	0.129	L.001	0.002	0.002	0.002	0.001	0.003	0.002	0.003	0.002	L.002	L.002	L.0001	L.001
		10-Oct-90	0.024	L.002	0.001	0.0012	0.086	0.085	L.001	0.002	0.003	0.001	0.002	0.003	0.003	0.002	0.002	L.002	L.002	L.0001	L.001

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE D/M/Y	Mo Diss. 42109L	Mn Total 25004L	Mn Diss. 25109L	Ni Total 28009L	Ni Diss. 28109L	Fe Total 26009L	Fe Diss. 26109L	Zn Total 30009L	V Total 23009L	V Diss. 23109L	Se Total 34005L	Se Diss. 34102L
BATTLE RIVER (SITE 5) AT HWY 21	00AL05FA0700	02-May-89	0.002	0.119	0.01	0.007	0.005	2.124	0.145	0.008	0.006	0.002	L.0001	L.0001
		30-May-89		0.082		0.007		1.036		L.001	0.005		L.0001	
		26-Jun-89		0.126		0.004		0.7		0.006	0.004		L.0001	
		25-Jul-89	0.002	0.183	0.023	0.004	0.004	0.774	0.14	0.004	0.004	0.004	L.0001	L.0001
		23-Aug-89		0.211		0.005		0.816		0.005	0.005		L.0001	
		27-Sep-89	0.002	0.13	0.005	0.005	0.005	0.722	0.18	0.002	0.004	0.003	L.0001	L.0001
		24-Oct-89	0.003	0.065	0.002	0.007	0.02	0.727	0.087	0.003	0.004	0.003	0.0001	0.0001
		09-Jan-90	0.003	0.067	0.058	0.006	0.007	0.57	0.064	0.001	0.003	0.003	0.0001	0.0001
		04-Apr-90	0.002	0.292	0.13	0.012	0.005	6.834	0.418	0.029	0.013	0.002	0.0002	0.0001
		22-May-90	0.002	0.084	0.003	0.004	0.004	0.56	0.066	0.001	0.004	0.003	0.0001	L.0001
		28-Aug-90	L.001	0.158	0.005	0.004	0.004	0.938	0.114	0.003	0.004	0.003	0.0001	0.0001
		09-Oct-90	0.003	0.104	0.072	0.006	0.005	0.669	0.081	0.003	0.004	0.003	L.0001	L.0001
CAMROSE CREEK NEAR MOUTH	00AL05FA0745	04-Apr-90	0.002	0.537	0.416	0.009	0.006	3.745	0.333	0.031	0.009	0.003	0.0002	0.0001
		22-May-90	0.002	0.248	0.03	0.008	0.01	1.297	0.028	0.007	0.007	0.005	0.0002	0.0001
		28-Aug-90	0.003	0.119	0.025	0.007	0.008	1.635	0.149	0.015	0.007	0.005	0.0002	0.0001
		09-Oct-90	0.003	0.238	0.184	0.013	0.01	0.984	0.008	0.011	0.008	0.007	0.0003	0.0003
BATTLE RIVER (SITE 6) D/S CAMROSE CR.	00AL05FA0750	02-May-89	0.002	0.117	0.017	0.007	0.006	1.718	0.153	0.015	0.005	0.002	L.0001	L.0001
		30-May-89		0.08		0.007		0.837		L.001	0.005		L.0001	
		26-Jun-89	0.002	0.155	0.003	0.005	0.006	0.711	0.111	0.004	0.004	0.003	L.0001	L.0001
		25-Jul-89	0.001	0.151	0.004	0.003	0.003	0.552	0.116	0.003	0.004	0.003	L.0001	L.0001
		23-Aug-89		0.182		0.005		0.812		0.004	0.005		L.0001	
		27-Sep-89	0.002	0.168	0.008	0.005	0.005	0.851	0.235	0.002	0.005	0.004	L.0001	L.0001
		24-Oct-89	0.002	0.075	0.004	0.006	0.005	0.718	0.113	0.003	0.004	0.003	0.0001	0.0001
		09-Jan-90	L.001	0.078	0.067	0.006	0.005	0.571	0.063	L.001	0.004	0.004	0.0001	0.0001
		07-Feb-90	0.002	0.135	0.13	0.005	0.005	0.462	0.048	0.003	0.004	0.003	0.0001	0.0001
		04-Apr-90	0.002	0.289	0.141	0.011	0.005	7.037	0.506	0.033	0.014	0.002	0.0002	L.0001
		22-May-90	0.001	0.093	0.003	0.004	0.004	0.512	0.055	0.002	0.004	0.003	0.0001	L.0001
		28-Aug-90	L.001	0.142	0.022	0.005	0.004	0.81	0.1	0.004	0.004	0.003	0.0001	0.0001
		09-Oct-90	0.004	0.134	0.096	0.004	0.005	0.647	0.061	0.004	0.004	0.003	L.0001	L.0001
BATTLE RIVER (SITE 7) AT HWY 850	00AL05FA1000	03-May-89	0.002	0.096	0.008	0.007	0.008	0.667	0.176	L.001	0.004	0.003	L.0001	L.0001
		30-May-89		0.096		0.005		0.287		L.001	0.004		L.0001	
		26-Jun-89		0.015		0.004		0.097		0.003	0.003		L.0001	
		25-Jul-89	0.002	0.025	0.003	0.003	0.002	0.159	0.058	0.002	0.003	0.002	L.0001	L.0001
		24-Aug-89		0.178		0.005		0.548		0.004	0.004		L.0001	
		27-Sep-89	0.003	0.129	0.013	0.006	0.006	0.457	0.056	0.003	0.007	0.006	0.0028	L.0001
		24-Oct-89	0.004	0.69	0.465	0.007	0.006	4.334	0.031	0.017	0.008	0.002	L.0001	0.0001
		10-Jan-90	0.002	0.197	0.166	0.004	0.004	0.2	0.033	L.001	0.003	0.003	0.0001	L.0001
		04-Apr-90	0.002	0.23	0.199	0.007	0.007	0.85	0.078	0.013	0.005	0.004	0.0001	0.0001
		28-May-90	0.003	0.107	0.005	0.003	0.005	0.331	0.051	L.001	0.003	0.003	0.0002	0.0001
		29-Aug-90	L.001	0.169	0.003	0.006	0.004	1.416	0.068	0.009	0.005	0.003	L.0001	L.0001
		10-Oct-90	0.002	0.206	0.005	0.017	0.013	2.108	0.07	0.013	0.008	0.004	0.0001	L.0001
MEETING CREEK NEAR MOUTH	00AL05FC0290	05-Apr-90	0.002	0.228	0.126	0.011	0.018	5.401	1.211	0.03	0.011	0.004	0.0002	0.0001
		28-May-90	0.002	0.206	0.003	0.008	0.007	0.778	0.021	0.003	0.005	0.004	0.0002	0.0002
		29-Aug-90	0.002	0.123	0.034	0.009	0.009	1.195	0.069	0.007	0.006	0.004	0.0002	0.0001
		10-Oct-90	0.001	0.088	0.035	0.01	0.009	0.339	0.042	0.01	0.005	0.004	0.0001	0.0001
BIG KNIFE CREEK NEAR MOUTH	00AL05FC0400	28-May-90	0.001	0.112	0.027	0.009	0.007	0.629	0.038	0.002	0.004	0.003	0.0002	0.0002
BATTLE RIVER (SITE 8) BIG KNIFE PROV. PK U/S FORESTBURG	00AL05FC0660	03-May-89	0.005	0.095	0.004	0.007	0.006	1.085	0.197	0.012	0.004	0.004	L.0001	L.0001
		30-May-89		0.114		0.006		0.301		L.001	0.004		L.0001	
		27-Jun-89		0.2		0.005		0.458		0.009	0.003		L.0001	
		26-Jul-89	0.002	0.135	0.004	0.005	0.007	0.79	0.085	0.005	0.005	0.003	L.0001	L.0001
		24-Aug-89		0.114		0.006		0.479		0.006	0.005		L.0001	
		28-Sep-89	0.004	0.113	0.006	0.006	0.009	0.227	0.024	0.002	0.005	0.005	L.0001	L.0001
		24-Oct-89	0.004	0.129	0.002	0.007	0.008	0.53	0.013	0.003	0.004	0.003	0.0002	0.0002
		10-Jan-90	0.002	0.259	0.236	0.007	0.006	0.399	0.041	0.002	0.004	0.003	L.0001	0.0001
		05-Apr-90	0.002	0.329	0.249	0.01	0.007	2.799	0.118	0.015	0.008	0.003	0.0002	L.0001
		28-May-90	0.002	0.139	0.003	0.007	0.009	0.636	0.039	0.001	0.005	0.004	0.0001	0.0001
		29-Aug-90	L.001	0.108	0.002	0.006	0.004	0.603	0.081	0.005	0.004	0.003	0.0001	L.0001
		10-Oct-90	L.001	0.156	0.04	0.005	0.005	0.271	0.012	0.003	0.003	0.003	L.0001	L.0001

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE D/M/Y	Al Ext. 13030L	Al Diss. 13109L	As Total 33005L	As Diss. 33102L	Ba Total 56009L	Ba Diss. 56109L	Be Diss. 04103L	Cd Total 48009L	Cd Diss. 48109L	Co Total 27009L	Co Diss. 27109L	Cr Total 24009L	Cr Diss. 24109L	Cu Total 29009L	Cu Diss. 29109L	Pb Ext. 82301L	Pb Diss. 82103L	Hg Total 80015L	Mo Total 42009L
BATTLE RIVER (SITE 9)	00AL05FC0680	03-May-89	0.13	0.046	0.0045	0.0019	0.087	0.073	L.001	0.001	0.004	0.002	L.001	0.002	L.001	0.004	0.003		0.003	L.0001	0.003
AT HWY 861		31-May-89	0.028		0.0048		0.074		L.001	L.001		0.001		0.003		0.004		0.002		L.0001	0.002
D/S FORESTBURG RES.		27-Jun-89	0.316		0.004		0.08		L.001	0.001		L.001		0.002		0.004		L.002		L.0001	0.003
		26-Jul-89	0.162	L.002	0.0057	0.0037	0.091	0.19	L.001	0.001	0.002	0.002	0.002	0.003	0.002	0.005	0.003	L.002	L.002	L.0001	0.002
		24-Aug-89	0.035		0.003		0.095		L.001	0.002		0.002		0.003		0.005		L.002		L.0001	0.003
		28-Sep-89	0.094	0.01	0.0029	0.0009	0.103	0.077	L.001	0.002	0.002	0.002	0.001	0.015	0.002	0.004	0.005	L.002	L.002	L.0001	0.005
		24-Oct-89	0.062	0.026	0.0014	0.0006	0.1	0.099	L.001	0.002	0.003	0.002	0.001	0.002	0.001	0.004	0.003	0.003	L.002	L.0001	0.003
		10-Jan-90	0.063	0.014	0.0016	0.0013	0.099	0.097	L.001	0.002	0.002	0.002	0.002	0.003	0.002	0.005	0.003	L.002	L.002	L.0001	0.003
		05-Apr-90	0.205		0.0053	0.0011	0.165	0.289	L.001	0.002	0.001	0.006	L.001	0.008	0.002	0.014	0.004	0.01	L.002	L.0001	0.006
		28-May-90	0.044	0.006	0.0026	0.0016	0.08	0.073	L.001	0.002	0.001	0.001	0.003	0.002	0.002	0.004	0.003	L.002	L.002	L.0001	0.002
		29-Aug-90	0.041	0.02	0.0029	0.002	0.105	0.093	L.001	0.002	0.002	0.001	L.001	0.003	0.003	0.003	0.002	L.002	L.002	L.0001	0.002
		10-Oct-90	0.033	0.01	0.0016	0.0014	0.098	0.096	L.001	0.002	0.002	0.001	L.001	0.004	0.004	0.003	0.003	L.002	L.002	L.0001	0.004
PAINTEARTH CREEK	00AL05FC0690	05-Apr-90	0.152		0.0048	0.0016	0.134	0.227	L.001	L.001	L.001	0.004	0.002	0.005	0.002	0.011	0.006	0.006	L.002	L.0001	0.004
AT MOUTH		28-May-90	0.131		0.0031	0.0008	0.095	0.075	L.001	0.001	L.001	0.002	0.002	0.003	0.002	0.004	0.003	0.005	0.004	L.0001	0.004
		29-Aug-90	0.051	0.025	0.0025	0.001	0.123	0.11	L.001	0.002	0.002	0.002	0.002	0.003	0.003	0.004	0.004	L.002	L.002	L.0001	0.003
CASTOR CREEK	00AL05FC0800	05-Apr-90																			
NEAR MOUTH		28-May-90	0.028	L.002	0.0015	0.001	0.073	0.071	L.001	0.002	0.002	0.002	0.002	0.003	0.003	0.004	0.002	L.002	L.002	L.0001	0.003
		29-Aug-90																			
BATTLE RIVER (SITE 10)	00AL05FC1000	03-May-89	0.264	0.182	0.0074	0.0015	0.132	0.092	L.001	0.002	0.001	0.004	L.001	0.007	L.001	0.009	0.006		0.006	L.0001	0.004
AT HWY 872		31-May-89	0.05		0.0045		0.069		L.001	0.001		0.002		0.003		0.004		0.003		L.0001	0.002
		27-Jun-89	0.054	0.056	0.003	0.002	0.075	0.07	L.001	L.001	L.001	0.001	0.001	L.001	L.001	0.004	0.005	L.002	L.002	L.0001	0.002
		26-Jul-89	0.157	0.083	0.002	0.0023	0.087	0.174	L.001	0.002	0.001	0.002	0.001	0.003	0.002	0.004	0.003	L.002	L.002	L.0001	0.003
		22-Aug-89	L.002		0.0015		0.063		L.001	0.002		L.001		0.002		0.002		L.002		L.0001	0.003
		28-Sep-89	0.017	L.002	0.0016	0.0009	0.066	0.071	L.001	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.003	L.002	L.002	L.0001	0.004
		24-Oct-89	0.048	0.012	0.0012	0.001	0.066	0.069	L.001	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.002	L.002	0.003	L.0001	0.003
		10-Jan-90	0.096	0.019	0.0018	0.0009	0.111	0.11	L.001	0.002	0.002	0.002	0.002	0.003	0.002	0.005	0.004	L.002	L.002	0.0001	0.003
		07-Feb-90	0.044	0.003	0.0015	0.0007	0.133	0.139	L.001	0.002	0.002	0.002	0.001	0.002	0.002	0.004	0.003	L.002	L.002	L.0001	0.005
		05-Apr-90	0.28		0.009	0.0013	0.22	0.223	L.001	0.002	L.001	0.01	0.001	0.011	0.002	0.02	0.004	0.013	L.002	L.0001	0.007
		28-May-90	0.058	L.002	0.0015	0.0009	0.085	0.075	L.001	0.002	0.002	0.002	0.001	0.002	0.002	0.004	0.003	L.002	L.002	L.0001	0.003
		29-Aug-90	0.041	0.017	0.0026	0.0015	0.11	0.12	L.001	0.002	0.002	0.002	L.001	0.003	0.002	0.004	0.003	L.002	L.002	L.0001	0.002
		10-Oct-90	0.024	0.01	0.0017	0.0011	0.094	0.094	L.001	0.002	0.002	L.001	0.002	0.002	0.002	0.004	0.002	0.003	L.002	L.002	0.0001	0.002
GRATTAN CREEK	00AL05FE0175	29-May-90	L.002		0.0028	0.0028	0.071	0.068	L.001	0.004	0.004	0.002	0.003	0.003	0.003	0.001	0.002	L.002	L.002	0.0001	0.002
BATTLE RIVER (SITE 11)	00AL05FB0500	03-May-89	0.068	0.036	0.0074	0.0017	0.134	0.081	L.001	0.002	0.001	0.004	0.002	0.005	0.001	0.008	0.007		0.004	L.0001	0.004
D/S HARDISTY		31-May-89	0.172		0.005		0.075		L.001	0.002		0.001		0.004		0.004		L.002		L.0001	0.002
		27-Jun-89	0.04		0.003		0.073		L.001	L.001		0.001		L.001		0.004		L.002		L.0001	0.002
		26-Jul-89	0.12	0.009	0.0023	0.0023	0.091	0.102	L.001	0.001	L.001	0.001	0.001	0.003	0.002	0.004	0.003	L.002	L.002	L.0001	0.003
		22-Aug-89	L.002		0.0023		0.078		L.001	0.002		0.001		0.003		0.002		L.002		L.0001	0.003
		28-Sep-89	0.01	0.003	0.0021	0.0017	0.063	0.062	L.001	0.002	0.002	0.003	0.002	0.003	0.003	0.003	0.003	L.002	L.002	L.0001	0.003
		24-Oct-89	0.026	L.002	0.0027	0.0017	0.06	0.059	L.001	0.002	0.002	0.001	0.001	0.002	0.002	0.001	0.001	L.002	L.002	L.0001	0.003
		10-Jan-90	0.055	0.014	0.0019	0.0008	0.099	0.098	L.001	0.003	0.001	0.002	0.003	0.003	0.002	0.004	0.003	L.002	L.002	L.0001	0.003
		10-Apr-90	0.951		0.0072	0.001	0.214	0.164	L.001	0.002	0.002	0.009	0.006	0.012	0.002	0.016	0.003	0.012	L.002	L.0001	0.006
		28-May-90	0.058		0.0017	0.0009	0.087	0.078	L.001	0.001	0.001	0.002	0.001	0.002	0.002	0.004	0.003	L.002	L.002	L.0001	0.002
		29-Aug-90	0.046	0.02	0.0028	0.0015	0.112	0.093	L.001	0.002	0.002	0.002	L.001	0.003	0.002	0.005	0.003	L.002	L.002	L.0001	0.003
		10-Oct-90	0.024	0.019	0.0013	0.001	0.099	0.098	L.001	0.002	0.002	0.001	0.001	0.003	0.006	0.003	0.003	L.002	L.002	L.0001	0.004
IRON CREEK	00AL05FB0700	10-Apr-90	0.598		0.0026	0.0017	0.06	0.133	L.001	0.002	0.002	0.002	0.005	0.006	0.003	0.003	0.003	L.002	L.002	L.0001	0.002
NEAR HARDISTY		28-May-90	L.002	L.002	0.0064	0.006	0.063	0.062	L.001	0.004	0.003	0.003	0.003	0.004	0.004	0.002	0.002	L.002	L.002	L.0001	0.003
		29-Aug-90	0.025	0.014	0.0079	0.0076	0.06	0.056	L.001	0.006	0.006	0.003	0.003	0.006	0.005	0.003	0.002	L.002	L.002	L.0001	0.004
		10-Oct-90	0.027	L.002	0.0053	0.005	0.064	0.06	L.001	0.006	0.006	0.003	0.003	0.007	0.007	0.004	0.002	L.002	0.002	L.0001	0.005
BATTLE RIVER (SITE 12)	00AL05FE0400	04-May-89	0.239	0.048	0.0073	0.0015	0.143	0.078	L.001	0.002	0.001	0.005	L.001	0.004	L.001	0.008	0.003		0.005	L.0001	0.005
AT HWY 41		31-May-89	0.041		0.0041		0.084		L.001	0.002		0.002		0.003		0.003		L.002		L.0001	0.002
		27-Jun-89	0.016		0.002		0.07		L.001	0.001		0.002		0.001		0.003		L.002		L.0001	0.003
		26-Jul-89	0.167	0.03	0.0045	0.0033	0.084	0.13	L.001	0.001	0.002	0.002	0.001	0.003	0.002	0.004	0.003	0.003	L.002	L.0001	0.002
		22-Aug-89	L.002		0.0028		0.064		L.001	0.002		0.001		0.005		0.002		L.002		L.0001	0.003
		28-Sep-89	0.01	L.002	0.0019	0.0015	0.091	0.088	L.001	0.002	0.002	0.002	0.002	0.003	0.003	0.002	0.003	L.002	L.002	L.0001	0.003
		24-Oct-89	0.034	0.012	0.0017	0.0014	0.085	0.089	L.001	0.003	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.003	0.002	L.0001	0.003
		11-Jan-90	0.027	0.014	0.0028	0.0017	0.115	0.112	L.001	0.002	0.002	0.001	0.002	0.002	0.003	0.002	0.002	L.002	L.002	0.0001	0.003
		10-Apr-90	0.912		0.0079	0.0008	0.214	0.149	L.001	0.002	0.001	0.009	0.009	0.011	0.002	0.017	0.003	0.005	L.002	L.0001	0.007
		29-May-90	0.037		0.0021	0.0012	0.092	0.083	L.001	L.001	0.001	0.002	0.001	0.003	0.002	0.004	0.002	L.002	0.002	L.0001	0.003
		30-Aug-90	0.144	0.007	0.0026	0.0014	0.11	0.102	L.001	0.002	0.002	0.002	L.001	0.003	0.002	0.005	0.003	L.002	L.002	L.0001	0.003
		11-Oct-90	0.03	L.002	0.0015	0.0008	0.101	0.126	L.001	0.003	0.002	L.001	L.001	0.001	L.001	L.001	L.001	L.002	L.002	L.0001	0.001

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE D/M/Y	Mo Diss. 42109L	Mn Total 25004L	Mn Diss. 25109L	Ni Total 28009L	Ni Diss. 28109L	Fe Total 26009L	Fe Diss. 26109L	Zn Total 30009L	V Total 23009L	V Diss. 23109L	Se Total 34005L	Se Diss. 34102L
BATTLE RIVER (SITE 9)	00AL05FC0680	03-May-89	0.002	0.168	0.003	0.009	0.009	1.601	0.119	0.005	0.007	0.003	L.0001	L.0001
AT HWY 861		31-May-89		0.11		0.007		0.467		L.001	0.004		L.0001	
D/S FORESTBURG RES.		27-Jun-89		0.098		0.006		0.55		0.005	0.005		L.0001	
		26-Jul-89	0.002	0.112	0.002	0.008	0.007	1.533	0.015	0.009	0.006	0.003	L.0001	L.0001
		24-Aug-89		0.136		0.01		1.406		0.008	0.005		L.0001	
		28-Sep-89	0.003	0.186	0.007	0.016	0.015	1.412	0.038	0.008	0.005	0.003	L.0001	L.0001
		24-Oct-89	0.003	0.111	0.04	0.01	0.011	1.06	0.087	0.006	0.004	0.002	L.0001	L.0001
		10-Jan-90	0.002	0.079	0.022	0.007	0.006	0.578	0.023	0.002	0.004	0.003	0.0002	0.0002
		05-Apr-90	0.002	0.347	0.061	0.016	0.007	8.283	0.795	0.044	0.016	0.003	0.0003	0.0002
		28-May-90	0.003	0.145	0.005	0.005	0.007	0.612	0.04	0.002	0.004	0.003	0.0002	0.0002
		29-Aug-90	L.001	0.124	0.002	0.006	0.005	0.873	0.025	0.003	0.004	0.003	0.0001	L.0001
		10-Oct-90	0.002	0.052	0.017	0.006	0.005	0.314	0.014	0.004	0.004	0.003	0.0001	0.0001
PAINTEARTH CREEK	00AL05FC0690	05-Apr-90	0.001	0.227	0.11	0.013	0.017	7.066	1.909	0.042	0.012	0.004	0.0003	0.0002
AT MOUTH		28-May-90	0.003	0.233	0.087	0.009	0.01	2.63	0.133	0.008	0.006	0.003	0.0002	0.0002
		29-Aug-90	0.002	0.293	0.128	0.012	0.012	1.58	0.033	0.006	0.005	0.003	0.0002	0.0001
CASTOR CREEK	00AL05FC0800	05-Apr-90												
NEAR MOUTH		28-May-90	0.002	0.208	0.11	0.006	0.007	0.72	0.048	0.002	0.005	0.004	0.0001	0.0001
		29-Aug-90												
BATTLE RIVER (SITE 10)	00AL05FC1000	03-May-89	0.002	0.317	0.002	0.014	0.011	4.66	0.1	0.028	0.011	0.003	L.0001	L.0001
AT HWY 872		31-May-89		0.117		0.008		0.602		L.001	0.005		L.0001	
		27-Jun-89	0.003	0.074	0.003	0.007	0.007	0.388	0.149	0.012	0.004	0.002	L.0001	L.0001
		26-Jul-89	0.003	0.103	0.012	0.006	0.006	0.988	0.025	0.006	0.005	0.003	L.0001	L.0001
		22-Aug-89		0.029		0.007		0.179		0.003	0.003		L.0001	
		28-Sep-89	0.004	0.063	0.049	0.006	0.008	0.3	0.021	0.003	0.004	0.003	L.0001	L.0001
		24-Oct-89	0.003	0.065	0.046	0.007	0.007	0.338	0.045	0.001	0.004	0.004	L.0001	0.0001
		10-Jan-90	0.004	0.084	0.041	0.008	0.008	0.981	0.032	0.007	0.005	0.003	0.0002	0.0002
		07-Feb-90	0.005	0.194	0.167	0.011	0.009	0.857	0.029	0.004	0.004	0.003	0.0002	0.0002
		05-Apr-90	0.002	0.484	0.017	0.024	0.009	13.471	1.203	0.068	0.024	0.003	0.0005	0.0001
		28-May-90	0.002	0.134	0.003	0.006	0.006	0.825	0.044	0.002	0.005	0.003	0.0001	L.0001
		29-Aug-90	0.002	0.124	0.002	0.007	0.007	1.08	0.02	0.004	0.005	0.003	0.0001	L.0001
		10-Oct-90	0.004	0.037	0.021	0.005	0.007	0.238	0.015	0.003	0.002	0.003	0.0001	L.0001
GRATTAN CREEK	00AL05FE0175	29-May-90	0.002	0.096	0.077	0.007	0.007	0.682	0.478	L.001	0.007	0.006	0.0001	0.0002
BATTLE RIVER (SITE 11)	00AL05FB0500	03-May-89	0.001	0.387	0.003	0.016	0.014	4.148	0.027	0.021	0.011	0.003	L.0001	0.0001
D/S HARDISTY		31-May-89		0.158		0.009		0.823		L.001	0.005		L.0001	
		27-Jun-89		0.108		0.006		0.409		0.007	0.003		L.0001	
		26-Jul-89	0.003	0.123	0.017	0.007	0.006	0.924	0.03	0.005	0.005	0.004	L.0001	L.0001
		22-Aug-89		0.072		0.005		0.185		0.002	0.004		L.0001	
		28-Sep-89	0.004	0.065	0.051	0.006	0.007	0.355	0.031	0.003	0.005	0.004	L.0001	L.0001
		24-Oct-89	0.003	0.103	0.082	0.006	0.007	0.6	0.029	0.001	0.004	0.003	0.0001	0.0001
		10-Jan-90	0.004	0.074	0.054	0.009	0.008	0.882	0.028	0.003	0.004	0.003	0.0002	0.0002
		10-Apr-90	0.001	0.415	0.005	0.024	0.008	11.881	0.303	0.053	0.022	0.003	0.0002	0.0002
		28-May-90	0.003	0.153	0.003	0.007	0.007	0.897	0.046	0.002	0.004	0.003	0.0001	0.0001
		29-Aug-90	L.001	0.161	0.003	0.007	0.007	1.391	0.039	0.006	0.006	0.003	0.0001	L.0001
		10-Oct-90	0.003	0.049	0.027	0.007	0.008	0.403	0.033	0.003	0.003	0.003	L.0001	L.0001
IRON CREEK	00AL05FB0700	10-Apr-90	0.001	0.119	0.051	0.007	0.006	2.341	0.606	0.014	0.007	0.004	0.0002	0.0001
NEAR HARDISTY		28-May-90	0.004	0.163	0.009	0.007	0.007	0.327	0.063	L.001	0.007	0.007	L.0001	L.0001
		29-Aug-90	0.004	0.151	0.035	0.008	0.009	0.541	0.116	0.003	0.008	0.007	L.0001	L.0001
		10-Oct-90	0.006	0.123	0.037	0.01	0.009	0.487	0.142	0.009	0.009	0.008	L.0001	L.0001
BATTLE RIVER (SITE 12)	00AL05FE0400	04-May-89	0.002	0.432	0.002	0.015	0.008	4.613	0.052	0.017	0.011	0.003	L.0001	L.0001
AT HWY 41		31-May-89		0.183		0.008		0.852		L.001	0.005		L.0001	
		27-Jun-89		0.094		0.006		0.348		0.003	0.004		L.0001	
		26-Jul-89	0.003	0.105	0.004	0.005	0.006	1.075	0.005	0.006	0.005	0.003	L.0001	L.0001
		22-Aug-89		0.028		0.009		0.242		0.003	0.003		L.0001	
		28-Sep-89	0.002	0.02	0.013	0.005	0.006	0.209	0.018	0.003	0.005	0.005	L.0001	L.0001
		24-Oct-89	0.002	0.03	0.02	0.004	0.006	0.353	0.031	0.002	0.005	0.004	0.0001	0.0001
		11-Jan-90	0.003	0.087	0.077	0.008	0.01	0.488	0.02	L.001	0.003	0.003	0.0001	0.0002
		10-Apr-90	0.002	0.453	0.006	0.021	0.007	12.281	0.511	0.055	0.021	0.003	0.0004	0.0002
		29-May-90	0.002	0.138	0.003	0.006	0.005	0.848	0.046	L.001	0.004	0.003	0.0002	0.0001
		30-Aug-90	0.003	0.13	0.002	0.008	0.005	1.242	0.057	0.013	0.005	0.003	0.0001	L.0001
		11-Oct-90	0.002	0.032	0.016	0.005	0.006	0.51	0.036	0.002	L.002	L.002	0.0001	0.0001

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE D/M/Y	Al Ext. 13030L	Al Diss. 13109L	As Total 33005L	As Diss. 33102L	Ba Total 56009L	Ba Diss. 56109L	Be Diss. 04103L	Cd Total 48009L	Cd Diss. 48109L	Co Total 27009L	Co Diss. 27109L	Cr Total 24009L	Cr Diss. 24109L	Cu Total 29009L	Cu Diss. 29109L	Pb Ext. 82301L	Pb Diss. 82103L	Hg Total 80015L	Mo Total 42009L
BUFFALO CREEK AT HWY 41	00AL05FE0500	10-Apr-90																			
		29-May-90	L.002	L.002	0.0031	0.0031	0.054	0.052	L.001	0.004	0.004	0.002	0.002	0.007	0.005	0.002	0.002	0.002	0.002	L.0001	0.002
		30-Aug-90																			
		11-Oct-90																			
GRIZZLY BEAR CREEK NEAR MOUTH	00AL05FE0600	10-Apr-90																			
		29-May-90	0.031	L.002	0.0064	0.006	0.066	0.064	L.001	0.005	0.005	0.004	0.005	0.006	0.006	0.003	0.004	0.003	L.002	L.0001	0.004
		30-Aug-90																			
BATTLE RIVER (SITE 13) AT HWY 897	00AL05FE0850	04-May-89	0.393	0.019	0.0092	0.0015	0.163	0.077	L.001	0.002	0.001	0.005	L.001	0.005	L.001	0.009	0.004		0.006	L.0001	0.005
		31-May-89	0.101		0.0045		0.087		L.001	0.002		0.002		0.004		0.003		0.002		L.0001	0.002
		27-Jun-89	0.03		0.002		0.074		L.001	0.001		L.001		0.001		0.004		L.002		L.0001	0.002
		26-Jul-89	0.12	0.04	0.0035	0.0025	0.061	0.082	L.001	L.001	0.002	L.001	0.001	0.002	0.002	0.004	0.003	L.002	L.002	L.0001	0.004
		22-Aug-89	L.002		0.0024		0.057		L.001	0.002		0.001		0.003		0.002		L.002		L.0001	0.003
		28-Sep-89	0.128	0.003	0.0027	0.001	0.095	0.085	L.001	0.002	0.002	0.003	0.002	0.004	0.003	0.003	0.002	L.002	L.002	L.0001	0.004
		24-Oct-89	0.041	0.019	0.0015	0.0009	0.074	0.071	L.001	0.002	0.002	0.002	0.001	0.003	0.003	0.002	0.002	L.002	L.002	L.0001	0.002
		11-Jan-90	0.035	0.014	0.002	0.0014	0.111	0.111	L.001	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.002	L.002	L.002	L.0001	0.003
		10-Apr-90	1.175		0.0108	0.001	0.263	0.203	L.001	0.003	0.002	0.012	0.026	0.014	0.002	0.023	0.005	0.01	L.002	L.0001	0.009
		29-May-90	0.058	0.006	0.0023	0.0013	0.093	0.08	L.001	0.002	0.002	0.003	0.017	0.003	0.002	0.004	0.003	L.002	L.002	L.0001	0.003
		30-Aug-90	0.23	0.007	0.0034	0.0015	0.112	0.116	L.001	0.002	0.002	0.002	0.001	0.004	0.003	0.005	0.004	L.002	L.002	L.0001	0.003
		11-Oct-90	0.033		0.0015		0.117		L.001	0.003		L.001		L.001		L.001		L.002		L.0001	0.003
RIBSTONE CREEK AT HWY 14	00AL05FE0875	10-Apr-90	0.165		0.0018	0.0012	0.073	0.094	L.001	0.002	0.002	0.001	0.003	0.004	0.003	0.002	0.002	L.002	L.002	L.0001	0.002
		29-May-90	0.062	L.002	0.0032	0.0026	0.109	0.112	L.001	0.002	0.003	0.003	0.002	0.004	0.003	0.002	0.002	0.002	L.002	L.0001	0.003
		30-Aug-90	0.09	0.007	0.0033	0.003	0.112	0.109	L.001	0.003	0.003	0.002	0.002	0.005	0.005	0.003	0.004	L.002	L.002	L.0001	0.002
		11-Oct-90	0.221	0.01	0.002	0.0016	0.107	0.108	L.001	0.005	0.005	L.001	L.001	0.003	0.003	0.001	L.001	L.002	L.002	L.0001	L.001
BLACKFOOT CREEK AT UNWIN ROAD	00AL05FE0890	10-Apr-90																			
		29-May-90	0.024	0.004	0.0036	0.0033	0.066	0.064	L.001	0.004	0.004	0.003	0.003	0.005	0.005	0.002	0.002	L.002	0.003	L.0001	0.003
		30-Aug-90																			
BATTLE RIVER (SITE 14) AT UNWIN	00SA05FE1000	04-May-89	0.416	0.046	0.0085	0.0013	0.166	0.082	L.001	0.002	0.002	0.005	0.001	0.006	L.001	0.01	0.003		0.01	L.0001	0.005
		30-May-89	L.002		0.0046		0.097		L.001	0.002		0.002		0.004		0.005		0.003		L.0001	0.002
		28-Jun-89	0.111	0.048	0.003	0.0007	0.087	0.079	L.001	L.001	0.002	0.002	L.001	L.001	L.001	0.002	0.002	0.003	L.002	L.0001	0.003
		03-Aug-89	0.12	L.002	0.0039	0.003	0.072	0.062	L.001	L.001	0.002	0.002	0.002	0.003	0.003	0.004	0.005	L.002	L.002	L.0001	0.003
		22-Aug-89	0.035		0.0024		0.072		L.001	0.003		0.001		0.002		0.003		L.002		L.0001	0.002
		26-Sep-89	0.039	L.002	0.0017	0.0009	0.075	0.074	L.001	0.003	0.003	0.002	0.002	0.003	0.003	0.002	0.002	L.002	L.002	L.0001	0.002
		24-Oct-89	0.062	0.01	0.0015	0.001	0.081	0.077	L.001	0.002	0.002	0.001	L.001	0.003	0.002	0.002	0.003	L.002	0.002	L.0001	0.002
		11-Jan-90	0.033	0.014	0.0019	0.0012	0.113	0.112	L.001	0.003	0.003	0.002	0.002	0.003	0.003	0.002	0.002	L.002	L.002	L.0001	0.003
		09-Feb-90	0.021	0.003	0.001	0.0009	0.136	0.138	L.001	0.002	0.003	0.001	0.002	0.002	0.002	0.002	L.001	L.002	L.002	L.0001	0.002
		10-Apr-90	1.571		0.0142	0.0011	0.296	0.149	L.001	0.003	0.001	0.014	0.01	0.017	0.002	0.027	0.004	0.003	L.002	L.0001	0.011
		29-May-90	0.113	L.002	0.0024	0.0014	0.093	0.079	L.001	0.001	0.002	0.002	0.001	0.004	0.004	0.004	0.003	0.002	L.002	L.0001	0.002
		30-Aug-90	0.267		0.0039		0.114		L.001	0.002		0.002		0.005		0.007		L.002		L.0001	0.004
		11-Oct-90	0.221	L.002	0.0017	0.0011	0.115	0.112	L.001	0.004	0.004	L.001	L.001	0.002	0.001	L.001	L.001	L.002	L.002	L.0001	L.001
BATTLE RIVER (SITE 15) AT HWY 40 NEAR MOUTH	00SA05FF1000	04-May-89	0.038	0.026	0.01	0.0014	0.161	0.082	L.001	0.002	0.002	0.006	L.001	0.008	L.001	0.011	0.003		0.003	L.0001	0.007
		30-May-89	0.016		0.0046		0.107		L.001	0.002		0.003		0.006		0.005		0.004		L.0001	0.003
		28-Jun-89	0.073	0.005	0.003	0.0025	0.083	0.079	L.001	L.001	0.002	0.001	L.001	L.001	L.001	0.002	0.001	L.002	L.002	L.0001	0.002
		03-Aug-89	0.011	L.002	0.0036	0.003	0.06	0.06	L.001	0.001	0.002	0.001	0.001	0.003	0.003	0.002	0.004	0.002	0.002	L.0001	0.003
		22-Aug-89	L.002		0.0023		0.051		L.001	0.002		L.001		0.002		0.002		L.002		L.0001	0.002
		26-Sep-89	0.005	0.006	0.0014	0.0009	0.064	0.064	L.001	0.002	0.002	0.002	0.002	0.003	0.003	0.002	0.002	L.002	L.002	L.0001	0.004
		24-Oct-89	0.039		0.0011	0.0008	0.08	0.079	L.001	0.002	0.003	0.002	0.001	0.003	0.003	0.001	0.003	L.002	L.002	L.0001	0.003
		11-Jan-90	0.016	0.005	0.0012	0.001	0.12	0.122	L.001	0.004	0.003	0.002	0.002	0.003	0.003	0.002	0.002	L.002	L.002	L.0001	0.003
		08-Feb-90	0.015	0.009	0.001	0.0009	0.147	0.147	L.001	0.002	0.002	0.002	0.002	0.004	0.003	0.003	0.002	L.002	L.002	L.0001	0.002
		10-Apr-90	2.232		0.0159	0.0011	0.362	0.165	0.001	0.004	0.002	0.017	0.012	0.024	0.003	0.033	0.004	L.002	L.002	L.0001	0.015

APPENDIX 1. WATER QUALITY DATA 1989 - 1990 SURVEYS (cont.)

STATION	CODE	DATE D/M/Y	Mo Diss. 42109L	Mn Total 25004L	Mn Diss. 25109L	Ni Total 28009L	Ni Diss. 28109L	Fe Total 26009L	Fe Diss. 26109L	Zn Total 30009L	V Total 23009L	V Diss. 23109L	Se Total 34005L	Se Diss. 34102L
BUFFALO CREEK AT HWY 41	00AL05FE0500	10-Apr-90												
		29-May-90	0.002	0.062	0.041	0.01	0.011	0.382	0.117	L.001	0.009	0.008	L.0001	0.0001
		30-Aug-90												
		11-Oct-90												
GRIZZLY BEAR CREEK NEAR MOUTH	00AL05FE0600	10-Apr-90												
		29-May-90	0.004	0.104	0.005	0.015	0.017	0.424	0.034	L.001	0.014	0.013	0.0002	0.0003
		30-Aug-90												
BATTLE RIVER (SITE 13) AT HWY 897	00AL05FE0850	04-May-89	0.002	0.481	0.002	0.016	0.009	5.745	0.022	0.019	0.013	0.003	L.0001	L.0001
		31-May-89		0.181		0.01		1.091		L.001	0.006		L.0001	
		27-Jun-89		0.101		0.007		0.473		0.003	0.004		L.0001	
		26-Jul-89	0.003	0.036	0.002	0.005	0.002	0.548	0.031	0.004	0.005	0.003	L.0001	L.0001
		22-Aug-89		0.019		0.004		0.316		0.004	0.004		L.0001	
		28-Sep-89	0.003	0.082	0.041	0.007	0.007	1.333	0.028	0.004	0.006	0.004	L.0001	L.0001
		24-Oct-89	0.002	0.022	0.013	0.006	0.006	0.358	0.032	0.003	0.005	0.004	0.0001	0.0001
		11-Jan-90	0.003	0.065	0.059	0.007	0.008	0.401	0.023	L.001	0.004	0.004	0.0002	0.0001
		10-Apr-90	0.001	0.612	0.006	0.028	0.008	18.161	0.719	0.074	0.029	0.003	0.0005	0.0002
		29-May-90	0.002	0.155	0.003	0.01	0.009	1.116	0.03	0.002	0.005	0.003	0.0002	0.0001
		30-Aug-90	0.002	0.16	0.002	0.009	0.009	1.807	0.031	0.007	0.006	0.004	0.0001	L.0001
		11-Oct-90		0.034		0.007		0.614		0.002	L.002		0.0001	
RIBSTONE CREEK AT HWY 14	00AL05FE0875	10-Apr-90	0.001	0.108	0.08	0.004	0.004	1.23	0.343	0.004	0.004	0.003	L.0001	L.0001
		29-May-90	0.002	0.05	0.021	0.007	0.007	0.637	0.131	L.001	0.007	0.006	0.0001	L.0001
		30-Aug-90	0.002	0.032	0.012	0.006	0.008	0.486	0.149	0.004	0.005	0.005	L.0001	L.0001
		11-Oct-90	L.001	0.028	0.015	0.006	0.007	0.496	0.065	0.004	0.004	0.003	0.0001	0.0001
BLACKFOOT CREEK AT UNWIN ROAD	00AL05FE0890	10-Apr-90												
		29-May-90	0.003	0.094	0.014	0.011	0.012	0.461	0.054	L.001	0.009	0.009	0.0003	0.0002
		30-Aug-90												
BATTLE RIVER (SITE 14) AT UNWIN	00SA05FE1000	04-May-89	0.002	0.488	0.009	0.018	0.009	6.498	0.018	0.023	0.015	0.004	L.0001	L.0001
		30-May-89		0.161		0.012		1.634		0.001	0.007		L.0001	
		28-Jun-89	L.001	0.111	0.002	0.006	0.005	0.727	0.022	0.004	0.008	0.003	L.0001	0.001
		03-Aug-89	0.004	0.047	0.003	0.007	0.015	0.739	0.055	0.003	0.006	0.005	L.0001	L.0001
		22-Aug-89		0.031		0.006		0.539		0.004	0.005		L.0001	
		26-Sep-89	0.002	0.027	0.013	0.006	0.006	0.354	0.02	0.002	0.006	0.005	L.0001	L.0001
		24-Oct-89	0.003	0.029	0.012	0.006	0.01	0.473	0.019	0.003	0.005	0.004	L.0001	L.0001
		11-Jan-90	0.003	0.051	0.044	0.009	0.008	0.369	0.021	0.002	0.004	0.004	0.0001	0.0001
		09-Feb-90	0.003	0.512	0.491	0.006	0.007	0.409	0.022	0.003	0.003	0.003	0.0001	0.0001
		10-Apr-90	0.001	0.739	0.008	0.034	0.007	22.301	0.902	0.089	0.033	0.003	0.0006	0.0001
		29-May-90	0.002	0.145	0.003	0.008	0.01	1.308	0.04	0.011	0.005	0.003	0.0001	0.0002
		30-Aug-90		0.178		0.01		2.319		0.01	0.007		0.0001	
		11-Oct-90	L.001	0.033	0.004	0.007	0.006	0.611	0.016	0.004	0.003	L.002	0.0001	0.0001
BATTLE RIVER (SITE 15) AT HWY 40 NEAR MOUTH	00SA05FF1000	04-May-89	0.003	0.453	0.002	0.018	0.008	7.188	0.024	0.024	0.018	0.003	L.0001	0.0002
		30-May-89		0.188		0.012		2.284		0.003	0.009		L.0001	
		28-Jun-89	L.001	0.121	0.002	0.006	0.003	0.578	0.019	0.006	0.009	0.003	L.0001	L.0001
		03-Aug-89	0.003	0.03	0.002	0.006	0.014	0.224	0.043	L.001	0.006	0.005	L.0001	L.0001
		22-Aug-89		0.023		0.005		0.159		0.004	0.004		L.0001	
		26-Sep-89	0.004	0.016	0.005	0.004	0.005	0.173	0.027	0.002	0.004	0.004	L.0001	L.0001
		24-Oct-89	0.003	0.019	0.008	0.006	0.008	0.241	0.02	0.001	0.004	0.004	L.0001	L.0001
		11-Jan-90	0.003	0.189	0.186	0.007	0.007	0.123	0.012	L.001	0.005	0.004	0.0001	0.0001
		08-Feb-90	0.003	0.838	0.811	0.008	0.007	0.354	0.024	0.004	0.004	0.004	0.0001	0.0001
		10-Apr-90	0.003	0.914	0.007	0.04	0.007	28.731	0.858	0.107	0.045	0.004	0.0005	0.0001

Appendix 2. Summary of discharge records at synoptic and tributary sites in 1989 and 1990:
A. Mainstem sites
B. Tributaries
C. Battle River near Ponoka during wastewater release by Ponoka in 1990

APPENDIX 2. SUMMARY OF DISCHARGE RECORDS AT SYNOPTIC AND TRIBUTARY SITES IN 1989 AND 1990. (Units in m^3/s)

A. MAINSTEM SITES													
SITE	1989							1990					
	MAY 2-4	MAY 29-31	JUNE 26-28	JULY 25 -AUG 3	AUG 21-23	SEPT 20	OCT 16	JAN 9-11	FEB 7-8	APRIL 3-10	MAY 22-29	AUG 28-30	OCT 9-11
Hwy 611 05FA923	1.88	2.59	0.624	0.672	0.804	0.470	0.565	NA	NA	8.58	3.68	2.68	1.23
Hwy 53 05FA001-05FA913	3.207	3.765	0.646	0.797	1.21	0.463	0.946	NA	NA	19.3	4.13	3.37	1.22
Near Hwy 2A WSC 05FA001	3.68	4.08	0.680	0.797	1.21	0.463	0.986	0.456	0.223	28.7	5.21	3.21	1.76
d/s Samson Lake 05FA919	10.8	6.80	2.67	0.319	0.646	0.470	0.463	NA	NA	17.0	4.01	3.61	1.68
Hwy 21 05FA924	13.1	7.80	1.91	0.440	0.641	0.604	1.02	NA	NA	32.7	6.17	4.57	2.22
d/s Camrose Creek 05FA924 & 05FA925	14.046	7.980	1.936	0.491	0.650	0.608	1.028	NA	NA	33.85	7.23	4.729	2.459
Hwy 850 05FA925	20.4	7.98	1.16	0.770	0.145	0.413	0.190	NA	NA	29.2	6.39	7.85	1.82
At Bigknife Prov. Park WSC 05FC001	19.0	7.03	2.73	1.16	0.410	0.221	0.586	NA	NA	31.4	6.98	6.62	1.99
Hwy 861 05FC905	18.3	6.40	4.13	2.05	0.007	0.015	0.076	NA	NA	(39.2)	5.90	7.89	2.12
Hwy 872 05FC906	18.6	6.47	2.99	1.64	0.045	0.055	0.054	NA	NA	(39.2)	5.71	7.68	1.94
d/s Hardisty 05FB903	(19.85)	6.46	3.563	2.53	0.177	0.168	0.190	NA	NA	(39.2)	7.27	9.13	2.62
Hwy 41 05FB903 & 05FB002	(19.85)	6.521	3.813	2.535	0.178	0.179	0.245	NA	NA	(39.2)	7.73	10.7	4.20
Hwy 897 05FE906	21.1	7.70	5.44	4.27	1.19	1.11	1.11	NA	NA	41.7	8.77	11.5	4.16
Near Unwin NSC 05FE004	21.4	9.22	5.210	4.22 E	1.33	1.22	1.15	1.400	0.672	43.5	10.300	11.500	4.420
Near Mouth WSC 05FF001	22.400	11.500	7.050	5.960	2.700	2.150	1.620	NA	NA	52.0	15.2	14.2	4.78

Discharge applies to day of water chemistry sampling, refer to Appendix 1 for exact date
Values in parenthesis are adjusted flows used in calculation of mass loads

APPENDIX 2. (cont.)

B. TRIBUTARIES				
SITE	**APRIL 3-10**	**MAY 22-23**	**AUGUST 28-30**	**OCTOBER 9-11**
Pigeon Lake Creek WSC 05FA019	2.09	1.58	2.13	0.862
Wolf Creek 05FA913	4.58	0.408	0.054	0.054
Pipstone Creek 05FA920	16.8	0.958	0.319	0.002
Camrose Creek 05FC921	1.15	1.06	0.159	0.239
Meeting Creek 05FC910	2.500	0.034	0.001	L0.001
Bigknife Creek 05FC907	1.32	0.036	L0.001	0.001
Paintearth Creek 05FC908	0.994	0.002	0.003	L0.001
Castor Creek 05FC909	1.91	0.005	NA	no flow (1)
Iron Creek 05FB002	3.00	0.106	0.017	0.002
Grattan Creek 05FB904	NA	0	NA	no flow (1)
Buffalo Creek	0.653	0.100	0.005	0.015
Grizzly Bear Creek 05FE907	NA	0.003	NA	NA
Ribstone Creek 05FD905	0.159	1.38	0.186	0.008
Blackfoot Creek 05FE908	NA	0.003	no flow (1)	dry (1)

(1) As observed by Environmental Quality Monitoring staff

APPENDIX 2. (cont.)

C. STATION NUMBER 05FA001 (BATTLE RIVER NEAR PONOKA) RIVER DISCHARGE DURING WASTEWATER RELEASE BY PONOKA IN 1990			
DATE	**DISCHARGE (m^3/s)**	**DATE**	**DISCHARGE (m^3/s)**
May 10, 1990	4.54	September 11, 1990	2.27
May 11, 1990	4.30	September 12, 1990	2.27
May 12, 1990	3.93	September 13, 1990	2.17
May 13, 1990	3.67	September 14, 1990	2.20
→ May 14, 1990	3.61	September 15, 1990	2.02
May 15, 1990	3.49	→ September 16, 1990	1.96
May 16, 1990	3.44	September 17, 1990	1.77
May 17, 1990	3.39	September 18, 1990	1.64
May 18, 1990	3.48	September 19, 1990	1.91
May 19, 1990	3.50	September 20, 1990	1.71
May 20, 1990	4.34	September 21, 1990	1.72
May 21, 1990	4.89	September 22, 1990	1.58
May 22, 1990	5.21	September 23, 1990	1.52
→ May 23, 1990	5.82	September 24, 1990	1.34
May 24, 1990	6.27	September 25, 1990	1.33
May 25, 1990	8.47	→ September 26, 1990	1.29
		September 27, 1990	1.37
		September 28, 1990	1.45
		September 29, 1990	1.35
		September 30, 1990	1.19

→ Indicate period during which wastewater discharge occurred and during which samples were collected

Appendix 3. Water quality data from the Battle River during the Ponoka wastewater surveys in 1990

APPENDIX 3 WATER QUALITY DATA FROM THE BATTLE RIVER DURING PONOKA WASTEWATER DISCHARGE (cont.)

DATE	CODE	DISCH.	TEMP.	PH	ALK TOT	SPEC. COND.	TDS	Ca	Mg	Na	K	HCO3	CO3	Cl	SO4	F	Si	DO	DO	BOD
D/M/Y	00AL05-	M3/S	DEG.C		mg/L	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
		97160S	02061F	10301F	10101L	02041L	00205L	20107L	12105L	11103L	19103L	06202L	06302L	17203L	16306L	09107L	14107L	08101L	08102F	08202L
BATTLE RIVER 3 KM u/s PONOKA WASTEWATER OUTFALL																				
14-May-90	FA0301	3.61	9	8.1															8.5	
15-May-90		3.49	9.4	8.5	226	455	255	46	16	32	4.6	270	3	4.9	15	0.14	2.9	12.23	12.5	3.9
16-May-90		3.44	10.4	8.4	227	456	257	46	16	33	4.7	272	3	4.9	16	0.14	2.5	12.2	12.3	3.4
17-May-90		3.39	10.5	8.3	228	452	257	46	16	32	4.6	268	5	4.9	16	0.13	1.9	9.96	10	3.4
18-May-90		3.48	11.5	8.2	227	455	254	46	16	32	4.7	270	3	4.1	15	0.14	1.6		8.9	2.2
19-May-90		3.5	11.7	8.2	227	453	254	47	16	31	4.6	266	5	4	15	0.14	1.5		9.4	1.9
20-May-90		4.34	12.7	8.3	231	458	258	48	17	31	4.8	276	3	3.9	15	0.14	1.5		10.4	2.5
21-May-90		4.89	12.7	8.1															8.1	
22-May-90		5.21	12.2	8.2	218	438	244	46	16	29	5.1	266		4.2	13	0.14	3.3	9.57	9	2
23-May-90		5.82	15.6	8.3	217	437	242	44	16	29	5.1	259	3	4.7	13	0.12	4.2	10.74	10.9	3.4
16-Sep-90		1.96	15.5	8															8.7	
17-Sep-90		1.77	13	8.2	174	341	185	33	14	19	4.8	209	2	1.8	8	0.14	6.4	8.3	8.6	4.2
18-Sep-90		1.84	12.7	8.3	179	349	192	34	13	23	4.6	215	2	2.4	8	0.12	6.3	8.78	8.9	3.7
19-Sep-90		1.91	12.8	8.2	179	350	190	34	14	21	4.6	218		2.1	7	0.13	6.9	8.85	9	5.5
20-Sep-90		1.71	12.3	8.2	180	353	192	33	13	23	4.7	219		2.2	8	0.12	6.7	8.52	8.9	4.3
21-Sep-90		1.72	12.3	8.2	179	350	193	33	13	23	4.9	215	1	2.3	9	0.12	7	8.64	8.6	3.9
22-Sep-90		1.58	12.3	8.2	179	349	194	34	13	23	5	217	L1.	2.3	9	0.13	6.8		8.7	4.1
23-Sep-90		1.52	12.3	8.2	179	350	189	32	13	23	4.7	214	2	2	7	0.13	6.7		8.7	4.1
24-Sep-90		1.34	12.7	8.2	178	348	190	33	13	24	4.8	212	3	2	6	0.13	6.9	9.06	9	4
25-Sep-90		1.33	12.3	8	180	351	188	31	13	21	4.8	217	1	1.9	8	0.11	6.7	8.28	7.7	4
26-Sep-90		1.29	13.5	8.3	182	356	196	35	14	22	4.9	222		2.2	9	0.12	6.6	10.05	9.7	2.9
BATTLE RIVER 4 KM D/S PONOKA WASTEWATER OUTFALL																				
14-May-90	FA0411		8.6	8.2															9.7	
15-May-90			9.9	9	282	625	377	49	19	70	5.6	299	22	11.9	51	0.24	3.8	14.75	16.5	13
16-May-90			10.5	9	288	645	389	48	19	76	5.8	308	21	13.2	53	0.27	4.3	15.58	15.8	10.9
17-May-90			10.8	8.9	276	609	365	48	19	68	5.7	316	10	11.6	46	0.23	3.3	14.13	14.2	9.2
18-May-90			11.4	8.8	276	611	361	48	18	65	5.6	302	17	10.6	46	0.24	2.8		12.2	9.6
19-May-90			12.4	8.9	274	612	359	48	19	64	5.6	291	21	10.4	46	0.24	2.6		13.9	10.3
20-May-90			13.2	8.8	268	584	344	49	18	59	5.4	297	14	9.2	41	0.23	2.2		14.3	6.9
21-May-90			13.3	8.5	260	560	327	48	18	54	5.4	273	21	8.1	36	0.21	1.8		10.1	12.8
22-May-90			13.4	8.7	244	517	295	46	17	45	5.3	297		6.8	27	0.19	2.2	12.67	11.9	7.2
23-May-90			16.1	8.5	225	456	254	44	16	33	5.1	262	6	5.2	16	0.14	2.8	12.64	12.8	4.7

DATE	CODE	DISCH.	TEMP.	PH	ALK TOT	SPEC. COND.	TDS	Ca	Mg	Na	K	HCO3	CO3	Cl	SO4	F	Si	DO	DO	BOD
D/M/Y	00AL05-	M3/S	DEG.C		mg/L	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
		97160S	02061F	10301F	10101L	02041L	00205L	20107L	12105L	11103L	19103L	06202L	06302L	17203L	16306L	09107L	14107L	08101L	08102F	08202L
BATTLE RIVER 4 KM D/S PONOKA WASTEWATER OUTFALL																				
16-Sep-90	FA0411		16.1	8.3															9.4	
17-Sep-90			13	8.1	181	356	197	35	14	22	4.9	217	2	2.3	10	0.14	5.6	7.79	8	4
18-Sep-90			12.9	8.5	222	493	286	37	15	50	5.6	261	5	9.9	35	0.21	7.5	7.55	7.6	3.4
19-Sep-90			13.3	8.4	250	580	348	38	16	67	5.9	293	6	16.2	54	0.27	8.3	7.47	7.4	3.6
20-Sep-90			12.7		249	590	349	39	17	69	6.2	290	7	13.7	54	0.26	8.3	7.45	7.8	4.2
21-Sep-90			12.7	8.4	241	562	328	37	15	62	5.7	284	5	12.8	50	0.25	8	7.95	7.9	4.3
22-Sep-90			12.6	8.4	245	579	346	39	17	68	6.1	281	9	13.7	55	0.26	8.1		7.7	4
23-Sep-90			12.8	8.5	240	561	333	38	16	64	6	276	8	12.8	52	0.24	8		7.9	4
24-Sep-90			12.9	8.5	225	514	300	37	15	54	5.6	258	8	10.6	42	0.23	7.3	7.94	7.8	4.1
25-Sep-90			12.7	8	214	479	272	33	15	47	5.5	252	4	9	34	0.2	6.7	7.55	7.5	4
26-Sep-90			12.4	8.4	186	367	203	36	14	25	5	226	L1.	2.7	9	0.13	6	9.71	9.3	3.1
BATTLE RIVER 8 KM D/S PONOKA WASTEWATER OUTFALL																				
14-May-90	FA0414		8.6																16.3	
15-May-90			9.9	9	264	571	340	49	18	58	5.4	290	16	9.8	41	0.21	1.8	14.9	16.2	8.6
16-May-90			10.5	9.1	290	652	397	49	19	78	5.8	303	25	14.2	56	0.28	3.4	15.22	14.4	10.4
17-May-90			10.9	9	274	597	365	48	19	68	5.5	254	40	11.5	48	0.23	2.7	14.12	12	9.4
18-May-90			11.4	8.8	276	602	358	47	19	63	5.6	276	30	10.4	46	0.24	2		14.1	8
19-May-90			12.4	8.8	270	603	354	48	18	64	5.6	282	23	10.3	45	0.24	1.9		15.2	8.6
20-May-90			13.7	8.8	269	591	348	48	18	62	5.4	279	24	10.3	42	0.24	1.7		10.1	7.7
21-May-90			13.1	8.5	258	559	327	48	18	55	5.4	272	21	8.3	37	0.21	1.3		11.1	8.9
22-May-90			13.3	8.5	245	517	297	46	17	46	5.2	292	3	6.9	28	0.18	1.6	12.05		4.9
23-May-90			15.5	8.5	226	463	260	44	16	36	5.1	259	8	5.7	17	0.14	2.1	12.96		4.8
16-Sep-90			15.7	8.2															9	
17-Sep-90			12.5	8.2	183	358	199	36	14	22	4.9	216	4	2.4	10	0.15	5.4	7.99	8.3	4.9
18-Sep-90			12.1	8.4	192	395	221	36	14	30	5	228	3	4.8	16	0.15	6	7.43	7.6	4
19-Sep-90			13.1	8.4	254	594	353	39	16	69	5.9	296	7	14.1	56	0.28	8.5	7.48	7.4	3.8
20-Sep-90			12.1		248	579	341	38	16	67	6	293	5	13.3	51	0.26	8	7.73	8.1	4.4
21-Sep-90			12.3	8.4	246	577	342	38	16	66	5.9	288	6	13.2	55	0.26	7.8	7.87	7.9	5.1
22-Sep-90			12.2	8.4	240	558	331	39	16	63	6	276	8	12.7	50	0.25	7.7		7.8	4.3
23-Sep-90			12.7	8.5	251	597	353	38	16	70	6.1	287	9	14.2	58	0.27	7.8		7.9	4.4
24-Sep-90			13.3	8.5	228	524	307	37	15	56	5.7	261	8	10.9	45	0.25	7	8.21	8.1	4.4
25-Sep-90			13.5	8.5	223	510	303	39	16	53	5.9	261	6	11.2	44	0.22	6.4	8.46	8.4	4.1
26-Sep-90			13	8.5	201	420	239	36	14	36	5.3	239	3	5.2	22	0.16	5.7	10.05	9.7	5.2

APPENDIX 3 WATER QUALITY DATA FROM THE BATTLE RIVER DURING PONOKA WASTEWATER DISCHARGE (cont.)

DATE	CODE	NFR	FR	Turb.	COLOUR TRUE	Diss. C	Part. C	Total P	Diss. N-NH3	N-NO3 NO2	N-NO2	TKN	N-Part Total	N Total	Plank. CHL-a	Total Colif	Fecal Colif.	Al	As	Ba
D/M/Y	00AL05-	mg/L 10401L	mg/L 10451L	NTU 02074L	RCU 02024L	mg/L 06107L	mg/L 06905L	mg/L 15421L	mg/L 07562L	mg/L 07105L	mg/L 07205L	mg/L 07021L	mg/L 07906L	mg/L 07602L	mg/m3 06715L	#/100mL 36001L	#/100m 36011L	Ext. 13030L	Total 33005L	Total 56009L
BATTLE RIVER 4 KM D/S PONOKA WASTEWATER OUTFALL																				
16-Sep-90	FA0411															410	410			
17-Sep-90		8	224	5.2	15	9	1.22	0.085	0.004	L.02	0.002	0.74	0.18	0.76	14.7	460	104	0.024	0.0024	0.087
18-Sep-90		11	318	6.9	17	9.4	1.1	0.455	0.179	L.02	0.005	1	0.17	1.02	11.8	150	100	0.024	0.0023	0.077
19-Sep-90		11	410	7.8	10	10.1	1.19	0.675	0.32	0.02	0.009	1.37	0.21	1.39	12.6	300	120	0.046	0.0025	0.078
20-Sep-90		9	390	6.1	21	10.1	1.43	0.68	0.35	0.03	0.013	1	0.35	1.03	11.5	120	72	0.034	0.0024	0.081
21-Sep-90		6	368	4.6	15	10.2	1.12	0.55	0.28	0.03	0.014	1.19	0.26	1.22	11.4	200	148	0.028	0.0023	0.081
22-Sep-90		9	380	5.4	12	9.7	1	0.54	0.3	0.04	0.016	1.29	0.19	1.33	11.1	270	184	0.022	0.0023	0.08
23-Sep-90		8	366	4.6	12	9.7	0.95	0.48	0.28	0.04	0.019	1.29	0.27	1.33	9.8	340	260	0.019	0.0035	0.08
24-Sep-90		9	332	5.9	13	9.4	1.07	0.35	0.186	0.04	0.019	1.1	0.22	1.14	12.4	192	140	0.028	0.002	0.086
25-Sep-90		10	318	6.3	16	9.3	1.31	0.265	0.138	0.04	0.019	1.03	0.23	1.07	19.3	530	200	0.041	0.0019	0.09
26-Sep-90		8	244	5.8	14	8.5	1.53	0.098	0.009	L.02	0.002	0.8	0.32	0.82	23.2			0.038	0.0014	0.093
BATTLE RIVER 8 KM D/S PONOKA WASTEWATER OUTFALL																				
14-May-90	FA0414															220	16			
15-May-90		10	384	4.6	38	12.5	2.22	0.365	0.26	0.1	0.018	1.64	0.4	1.74		150	10	0.011	0.0016	0.059
16-May-90		6	434	6.4	36	12.5	3.93	0.585	0.5	0.15	0.027	2.2	0.74	2.35		440	48	0.023	0.0003	0.051
17-May-90		7	402	4.8	32	12.1	4.26	0.49	0.28	L.02	0.027	1.85	0.79	1.87		320	10	0.011	0.0009	0.064
18-May-90		6	392	4.3	36	11.9	3.62	0.545	0.46	0.16	0.036	1.85	0.67	2.01		180	L10.	0.013	0.0017	0.066
19-May-90		5	400	4.3	28	11.6	4.53	0.555	0.6	0.16	0.043	1.95	0.86	2.11		190	10	0.01	0.0013	0.066
20-May-90		5	386	4.3	28	11.7	4.04	0.505	0.38	0.17	0.051	1.94	0.39	2.11		270	44	0.007	0.0017	0.067
21-May-90		6	358	4.7	30	11.9	3.23	0.4	0.25	0.13	0.045	1.73	0.58	1.86		1000	16	0.007	0.0017	0.066
22-May-90		6	330	5.1	40	12.3	1.45	0.34	0.23	0.13	0.044	1.46	0.24	1.59				0.023	0.0026	0.07
23-May-90		4	302	3.3	29	11.9	0.87	0.2	0.03	0.04	0.015	0.98	0.15	1.02				0.016	0.0017	0.071
16-Sep-90																530	176			
17-Sep-90		8	216	6.4	15	9.2	1.15	0.082	0.005	L.02	0.001	0.72	0.18	0.74	14.1	152	92	0.027	0.0028	0.086
18-Sep-90		8	254	5.8	19	9.5	1.48	0.176	0.024	L.02	0.002	0.77	0.14	0.79	12.2	2400	110	0.021	0.0017	0.091
19-Sep-90		8	402	7.6	8	10.6	1.12	0.685	0.196	0.03	0.009	1.12	0.16	1.15	9.4	790	100	0.043	0.0026	0.078
20-Sep-90		8	380	5.2	11	10.5	1.24	0.62	0.23	0.03	0.012	1.17	0.18	1.2	10.9	210	120	0.037	0.0024	0.079
21-Sep-90		7	380	4.9	10	10.6	1.12	0.585	0.21	0.04	0.014	1.15	0.19	1.19	10.5	208	184	0.034	0.0024	0.08
22-Sep-90		10	376	6	13	9.8	1.22	0.495	0.197	0.04	0.015	1.18	0.21	1.22	11	104	104	0.022	0.0022	0.081
23-Sep-90		7	366	4.4	14	10.2	0.91	0.54	0.23	0.05	0.021	1.28	0.18	1.33	8.3	188	136	0.025	0.0038	0.078
24-Sep-90		7	342	4.4	12	9.7	1.08	0.36	0.122	0.05	0.021	1.04	0.2	1.09	9.4	196	144	0.025	0.0021	0.081
25-Sep-90		7	336	4.8	17	9.7	1.18	0.305	0.095	0.06	0.021	0.97	0.23	1.03	11.2	310	184	0.041	0.002	0.086
26-Sep-90		5	276	4.8	15	9.2	1.16	0.173	0.037	0.03	0.011	0.88	0.28	0.91	13.7			0.025	0.0017	0.085

DATE	CODE	NFR	FR	Turb.	COLOUR TRUE	Diss. C	Part. C	Total P	Diss. N-NH3	N-NO3 NO2	N-NO2	TKN	N-Part Total	N Total	Plank. CHL-a	Total Colif	Fecal Colif.	Al	As	Ba
D/M/Y	00AL05-	mg/L	mg/L	NTU	RCU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/m3	#/100mL	#/100m	Ext.	Total	Total
		10401L	10451L	02074L	02024L	06107L	06905L	15421L	07562L	07105L	07205L	07021L	07906L	07602L	06715L	36001L	36011L	13030L	33005L	56009L
BATTLE RIVER 3 KM u/s PONOKA WASTEWATER OUTFALL																				
14-May-90	FA0301															90	6			
15-May-90		4	276	3.2	38	11.5	0.32	0.146	0.056	0.12	0.011	0.92	0.07	1.04		350	10	0.005	0.0012	0.074
16-May-90		4	286	3.7	36	11.4	0.45	0.176	0.056	0.12	0.011	0.97	0.1	1.09		168	8	0.005	0.0003	0.077
17-May-90		4	290	2.8	37	10.8	0.52	0.14	0.028	0.06	0.009	0.86	0.11	0.92		160	20	0.014	0.0003	0.075
18-May-90		4	284	3	29	10.7	0.63	0.127	0.02	0.06	0.006	0.81	0.07	0.87		60	L4.	L.002	0.0015	0.075
19-May-90		3	284	2.5	26	10.6	0.47	0.126	0.03	0.04	0.005	0.76	0.1	0.8		480	24	L.002	0.0017	0.075
20-May-90		4	290	3.1	30	11.1	0.54	0.13	0.013	L.02	0.003	0.84	0.08	0.86				0.013	0.0014	0.078
21-May-90																				
22-May-90		6	278	4.4	31	11.4	0.8	0.145	0.026	0.02	0.004	0.85	0.11	0.87				0.016	0.0019	0.077
23-May-90		5	298	4.2	30	11.5	0.73	0.13	0.017	L.02	0.003	0.8	0.09	0.82				0.023	0.0023	0.074
16-Sep-90																90	12			
17-Sep-90		12	216	7.8	15	9.1	1.53	0.069	0.004	L.02	0.001	0.72	0.21	0.74	15.3		4	0.031	0.002	0.088
18-Sep-90		13	226	8	14	8.9	1.78	0.072	0.01	L.02	0.001	0.73	0.21	0.75	16.9	190	8	0.027	0.0014	0.09
19-Sep-90		15	240	5.2	4	9.6	2.22	0.072	0.014	L.02	0.001	0.79	0.25	0.81	13.3	160	16	0.055	0.0016	0.112
20-Sep-90		11	230	6	10	8.7	1.37	0.071	0.061	L.02	0.001	0.71	0.22	0.73	10.9	2000	12	0.055	0.0014	0.101
21-Sep-90		10	234	6.2	8	8.6	1.19	0.067	0.015	L.02	0.001	0.7	0.19	0.72	10.7	40	8	0.043	0.0014	0.098
22-Sep-90		16	228	11.1	8	8.1	1.26	0.069	0.008	L.02	0.001	0.77	0.29	0.79	11.5	33	L4.	0.046	0.0014	0.1
23-Sep-90		15	236	10.4	9	8.2	1.4	0.071	0.007	L.02	0.001	0.78	0.23	0.8	13.8	2200	L4.	0.055	0.002	0.101
24-Sep-90		14	236	9	9	8.2	1.36	0.067	0.012	L.02	0.001	0.72	0.2	0.74	11.2	170	8	0.049	0.0015	0.101
25-Sep-90		14	240	8.6	13	8.3	1.45	0.07	0.011	L.02	0.001	0.76	0.25	0.78	13.6	310	8	0.053	0.0014	0.102
26-Sep-90		12	246	8.6	14	8.4	1.94	0.069	0.006	L.02	0.001	0.78	0.29	0.8	15.1			0.071	0.0014	0.099
BATTLE RIVER 4 KM D/S PONOKA WASTEWATER OUTFALL																				
14-May-90	FA0411															450	80			
15-May-90		16	410	7.4	36	13	5	0.555	0.63	0.14	0.02	2.35	0.9	2.49		260	L10.	0.02	0.0019	0.059
16-May-90		19	424	8.9	37	12.5	4.64	0.64	0.77	0.12	0.022	2.7	0.88	2.82		670	39	0.005	0.0003	0.057
17-May-90		7	400	4.8	35	11.7	4.48	0.605	0.74	L.02	0.024	2.5	0.84	2.52		410	10	0.023	0.0017	0.068
18-May-90		8	392	5.6	33	11.4	3.65	0.6	0.87	0.13	0.037	2.25	0.68	2.38		200	L10.	0.01	0.0019	0.068
19-May-90		10	396	6.6	29	11.5	3.6	0.605	0.9	0.14	0.045	2.25	0.67	2.39		3400	12	0.019	0.0018	0.07
20-May-90		5	374	4.7	27	11.4	3.58	0.505	0.58	0.13	0.042	1.9	0.65	2.03				0.01	0.0016	0.067
21-May-90		13	370	9.3	33	11.7	4.41	0.47	0.45	0.13	0.052	1.95	0.78	2.08				0.036	0.0016	0.072
22-May-90		14	334	10.2	35	11.7	2.48	0.38	0.35	0.15	0.058	1.7	0.4	1.85				0.053	0.0022	0.075
23-May-90		6	294	5	35	11.3	1.02	0.19	0.02	0.03	0.01	0.99	0.16	1.02				0.03	0.0018	0.072

APPENDIX 3 WATER QUALITY DATA FROM THE BATTLE RIVER DURING PONOKA WASTEWATER DISCHARGE (cont.)

DATE	CODE	Be	Cd	Co	Cr	Cu	Pb	Hg	Mo	Mn	Ni	Fe	Zn	V	Se
D/M/Y	00AL05-	Diss. 04103L	Total 48009L	Total 27009L	Total 24009L	Total 29009L	Ext. 82301L	Total 80015L	Total 42009L	Total 25004L	Total 28009L	Total 26009L	Total 30009L	Total 23009L	Total 34005L
BATTLE RIVER 3 KM u/s PONOKA WASTEWATER OUTFALL															
14-May-90	FA0301														
15-May-90		L.001	L.001	L.001	0.003	0.003	L.002	L.0001	0.001	0.035	0.006	0.277	0.004	0.003	L.0001
16-May-90		L.001	0.001	L.001	0.004	0.001	L.002	L.0001	L.001	0.04	0.004	0.3	0.003	0.003	L.0001
17-May-90		L.001	0.002	L.001	0.003	0.001	L.002	L.0001	L.001	0.042	0.004	0.345	0.003	0.003	L.0001
18-May-90		L.001	0.001	L.001	0.004	0.002	L.002	L.0001	0.002	0.038	0.004	0.332	0.003	0.003	L.0001
19-May-90		L.001	0.002	L.001	0.002	0.001	L.002	L.0001	0.002	0.032	0.005	0.318	0.002	0.003	L.0001
20-May-90		L.001	0.002	L.001	0.003	0.001	L.002	L.0001	0.003	0.04	0.005	0.335	0.002	0.003	L.0001
21-May-90															
22-May-90		L.001	0.002	0.001	0.003	L.001	L.002	L.0001	0.002	0.048	0.005	0.368	0.011	0.004	0.0001
23-May-90		L.001	0.001	L.001	0.002	L.001	L.002	L.0001	0.002	0.038	0.002	0.342	L.001	0.003	0.0001
16-Sep-90															
17-Sep-90		L.001	0.001	L.001	0.002	0.001	L.002	L.0001	L.001	0.077	0.003	0.402	0.003	0.003	L.0001
18-Sep-90		L.001	0.001	L.001	0.003	0.001	L.002	L.0001	L.001	0.075	0.003	0.471	0.002	0.003	L.0001
19-Sep-90		L.001	0.003	L.001	0.006	0.003	L.002	L.0001	0.002	0.083	0.011	0.507	0.012	0.003	L.0001
20-Sep-90		L.001	0.002	0.001	0.003	0.002	L.002	L.0001	0.001	0.068	0.004	0.465	0.006	0.003	L.0001
21-Sep-90		L.001	0.001	L.001	0.003	0.002	L.002	L.0001	0.002	0.067	0.003	0.449	0.004	0.003	L.0001
22-Sep-90		L.001	0.001	L.001	0.003	0.002	L.002	L.0001	L.001	0.074	0.004	0.575	0.004	0.003	L.0001
23-Sep-90		L.001	0.003	L.001	0.003	0.002	L.002	L.0001	0.001	0.077	0.003	0.579	0.004	0.003	L.0001
24-Sep-90		L.001	0.002	L.001	0.003	0.001	L.002	L.0001	L.001	0.073	0.01	0.525	0.003	0.003	L.0001
25-Sep-90		L.001	0.002	L.001	0.003	0.002	L.002	L.0001	0.003	0.074	0.003	0.472	0.003	0.003	L.0001
26-Sep-90		L.001	0.002	L.001	0.003	0.002	L.002	L.0001	0.003	0.077	0.004	0.509	0.006	0.004	L.0001
BATTLE RIVER 4 KM D/S PONOKA WASTEWATER OUTFALL															
14-May-90	FA0411														
15-May-90		L.001	L.001	0.001	0.003	0.003	L.002	L.0001	0.002	0.058	0.006	0.284	0.003	0.004	0.0001
16-May-90		L.001	0.001	0.001	0.004	0.001	L.002	L.0001	0.003	0.062	0.006	0.284	0.003	0.004	L.0001
17-May-90		L.001	0.001	L.001	0.003	0.002	0.002	L.0001	L.001	0.076	0.006	0.334	0.004	0.004	L.0001
18-May-90		L.001	L.001	L.001	0.003	0.001	L.002	L.0001	0.002	0.072	0.004	0.343	0.003	0.003	0.0001
19-May-90		L.001	0.002	L.001	0.004	0.001	L.002	L.0001	0.002	0.073	0.005	0.363	0.006	0.004	L.0001
20-May-90		L.001	0.002	L.001	0.003	0.002	L.002	L.0001	0.002	0.057	0.005	0.288	0.003	0.004	L.0001
21-May-90		L.001	0.002	0.001	0.004	0.002	L.002	L.0001	0.003	0.073	0.006	0.451	0.004	0.004	L.0001
22-May-90		L.001	0.001	0.001	0.003	0.001	L.002	L.0001	L.001	0.072	0.004	0.517	0.002	0.004	0.0001
23-May-90		L.001	0.001	L.001	0.002	L.001	L.002	L.0001	0.002	0.048	0.004	0.335	0.001	0.003	0.0001

APPENDIX 3 WATER QUALITY DATA FROM THE BATTLE RIVER DURING PONOKA WASTEWATER DISCHARGE (cont.)

DATE	CODE	Be	Cd	Co	Cr	Cu	Pb	Hg	Mo	Mn	Ni	Fe	Zn	V	Se
D/M/Y	00AL05-	Diss. 04103L	Total 48009L	Total 27009L	Total 24009L	Total 29009L	Ext. 82301L	Total 80015L	Total 42009L	Total 25004L	Total 28009L	Total 26009L	Total 30009L	Total 23009L	Total 34005L
BATTLE RIVER 4 KM D/S PONOKA WASTEWATER OUTFALL															
16-Sep-90	FA0411														
17-Sep-90		L.001	0.002	0.001	0.003	0.002	L.002	L.0001	0.001	0.078	0.003	0.342	0.005	0.003	L.0001
18-Sep-90		L.001	0.002	L.001	0.002	0.001	L.002	0.0001	0.001	0.08	0.004	0.356	0.003	0.003	L.0001
19-Sep-90		L.001	0.002	L.001	0.003	0.002	L.002	L.0001	0.002	0.095	0.005	0.42	0.006	0.003	L.0001
20-Sep-90		L.001	0.002	0.001	0.003	0.002	L.002	0.0001	0.001	0.09	0.004	0.36	0.009	0.004	L.0001
21-Sep-90		L.001	0.003	0.001	0.003	0.002	L.002	L.0001	0.002	0.078	0.004	0.275	0.005	0.004	L.0001
22-Sep-90		L.001	0.002	0.001	0.003	0.002	L.002	L.0001	0.001	0.077	0.003	0.26	0.003	0.004	L.0001
23-Sep-90		L.001	0.002	0.001	0.003	0.002	L.002	L.0001	L.001	0.071	0.004	0.247	0.003	0.003	L.0001
24-Sep-90		L.001	0.002	0.001	0.003	L.001	L.002	L.0001	L.001	0.076	0.003	0.32	0.001	0.003	L.0001
25-Sep-90		L.001	0.002	L.001	0.003	0.002	L.002	L.0001	L.001	0.077	0.004	0.29	0.004	0.004	L.0001
26-Sep-90		L.001	0.002	L.001	0.003	0.002	L.002	L.0001	0.001	0.08	0.004	0.3	0.006	0.004	L.0001
BATTLE RIVER 8 KM D/S PONOKA WASTEWATER OUTFALL															
14-May-90	FA0414														
15-May-90		L.001	L.001	0.001	0.003	0.001	L.002	L.0001	0.001	0.033	0.005	0.2	0.003	0.003	0.0001
16-May-90		L.001	L.001	0.001	0.006	0.002	0.002	L.0001	0.003	0.044	0.007	0.204	0.002	0.004	L.0001
17-May-90		L.001	0.001	0.001	0.005	0.002	L.002	L.0001	L.001	0.052	0.005	0.263	0.002	0.004	L.0001
18-May-90		L.001	L.001	L.001	0.003	0.002	L.002	L.0001	0.001	0.057	0.003	0.269	0.003	0.003	L.0001
19-May-90		L.001	0.002	0.001	0.003	0.002	L.002	L.0001	0.002	0.053	0.005	0.259	0.004	0.004	L.0001
20-May-90		L.001	0.002	0.001	0.004	0.003	L.002	L.0001	0.002	0.049	0.006	0.253	0.007	0.004	L.0001
21-May-90		L.001	0.001	L.001	0.004	0.002	L.002	L.0001	0.002	0.045	0.004	0.267	0.004	0.004	L.0001
22-May-90		L.001	0.001	L.001	0.003	L.001	L.002	L.0001	L.001	0.046	0.005	0.325	0.001	0.003	0.0001
23-May-90		L.001	L.001	L.001	0.002	L.001	L.002	L.0001	0.002	0.037	0.003	0.251	L.001	0.003	0.0001
16-Sep-90															
17-Sep-90		L.001	0.002	L.001	0.003	0.001	L.002	L.0001	0.002	0.073	0.004	0.319	0.004	0.003	L.0001
18-Sep-90		L.001	0.002	L.001	0.003	0.001	L.002	L.0001	L.001	0.067	0.004	0.348	0.004	0.003	L.0001
19-Sep-90		L.001	0.002	L.001	0.003	0.002	L.002	L.0001	0.002	0.066	0.005	0.302	0.008	0.003	L.0001
20-Sep-90		L.001	0.002	0.001	0.003	0.002	L.002	L.0001	0.002	0.074	0.003	0.324	0.008	0.004	L.0001
21-Sep-90		L.001	0.002	0.001	0.003	0.002	L.002	L.0001	0.004	0.069	0.008	0.298	0.01	0.003	L.0001
22-Sep-90		L.001	0.002	0.001	0.003	0.002	L.002	L.0001	L.001	0.065	0.003	0.252	0.004	0.003	L.0001
23-Sep-90		L.001	0.003	0.001	0.003	0.002	L.002	L.0001	L.001	0.056	0.005	0.246	0.004	0.004	L.0001
24-Sep-90		L.001	0.002	L.001	0.003	0.002	L.002	L.0001	0.003	0.055	0.004	0.254	0.004	0.004	L.0001
25-Sep-90		L.001	0.002	L.001	0.003	0.002	L.002	L.0001	0.001	0.056	0.003	0.267	0.004	0.004	0.0001
26-Sep-90		L.001	0.003	L.001	0.003	0.002	L.002	L.0001	0.002	0.061	0.004	0.268	0.007	0.003	L.0001

Appendix 4. Benthic invertebrate data collected at mainstem sites in 1989

BATTLE RIVER - D/S MUSKEG CR., AT HWY 611
00AL05FA0250

May 9, 1989

ANNELIDA					
HIRUDINEA					
PHARYNGOBDELLIDA					
Erpobdellidae					
Nephelopsis	0	1	1	0	0
RHYNCHOBDELLIDA					
Glossiphonidae					
Helobdella stagnalis	2	0	1	3	0
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	1	0	0	0	0
Naididae	17	9	13	5	7
Tubificidae	104	57	63	140	28
ARTHROPODA					
ARACHNOIDA					
ACARI	0	1	0	0	1
CRUSTACEA					
COPEPODA					
Cyclopoida	4	7	2	3	10
Calanoida	0	1	0	0	0
MALACOSTRACA					
Amphipoda					
Gammarus lacustris	1	0	1	0	6
Hyalella azteca	14	7	35	3	9
OSTRACODA	1	0	0	0	0
INSECTA					
COLEOPTERA					
Chrysomelidae	0	1	0	1	0
DIPTERA					
Ceratopogonidae	1	4	6	10	2
Chironomidae	0	0	1	0	0
Chironomini	5	3	11	4	7
Orthocladiinae	2	0	0	1	0
Tanypodinae	3	6	0	12	4
Tanytarsini	33	9	66	13	16
Simuliidae					
Simulium	3	2	4	12	4
Tabanidae					
Tabanus	0	1	0	0	0
EPHEMEROPTERA					
Caenidae					
Caenis	1	0	3	0	1
TRICHOPTERA					
Leptoceridae					
Oecetis	0	0	0	1	0
Triaenodes	1	0	0	0	0
Limnephilidae					
Nemotaulius	0	0	0	0	1
Molannidae					
Molanna	0	1	0	1	1
MOLLUSCA					
GASTROPODA					
PULMONATA					
Lymnaeidae					
Lymnaea	1	0	0	0	0
Planorbidae					
Planorbula	1	0	0	0	0
PELECYPODA					
BIVALVIA					
Sphaeriidae	21	5	22	14	8
Pisidium	11	0	3	0	0
Sphaerium	1	0	1	0	1
NEMATODA	16	16	35	47	18

BATTLE RIVER - D/S MUSKEG CR., AT HWY 611

00AL05FA0250

Oct. 10, 1989

ANNELIDA					
HIRUDINEA					
PHARYNGOBDELLIDA					
Erpobdellidae	0	0	0	2	2
RHYNCHOBDELLIDA					
Glossiphonidae					
Helobdella stagnalis	0	2	2	0	5
Theromyzon	0	0	0	1	0
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	0	8	0	3	1
Naididae	2	6	2	0	6
Tubificidae	79	256	43	66	84
ARTHROPODA					
CRUSTACEA					
COPEPODA					
Cyclopoida	1	0	1	0	2
MALACOSTRACA					
Amphipoda					
Gammarus lacustris	0	10	2	16	19
Hyalella azteca	68	85	25	68	142
OSTRACODA	0	0	0	0	1
INSECTA					
COLEOPTERA					
Chrysomelidae					
Donacia	0	2	0	2	0
Dytiscidae	0	0	0	0	1
DIPTERA					
Ceratopogonidae	7	6	7	9	2
Chironomidae					
Chironomini	10	33	17	24	20
Orthocladiinae	0	0	1	0	2
Tanypodinae	0	10	6	4	2
Tanytarsini	61	246	88	15	113
Tabanidae					
Chrysops	0	0	0	1	0
EPHEMEROPTERA					
Baetidae					
Callibaetis	4	0	0	0	5
Caenidae					
Caenis	0	3	0	0	0
HEMIPTERA					
Corixidae					
Corisella	0	0	0	0	1
ODONATA					
Coenagrionidae					
Enallagma	0	1	0	2	0
Coridulidae					
Somatochlora	0	0	0	0	1
TRICHOPTERA					
Leptoceridae					
Oecetis	2	0	1	0	0
Triaenodes	0	1	2	0	2
Limnephilidae					
Nemotaulius	0	0	0	2	0
Molannidae					
Molanna	2	1	0	3	0
Phryganeidae					
Ptiolstomis	0	0	0	0	1
Polycentropodidae					
Polycentropus	0	2	0	0	0
MOLLUSCA					
PELECYPODA					
BIVALVIA					
Sphaeriidae	655	240	58	801	9
Pisidium	4	14	1	22	2
Sphaerium	0	0	1	0	0
NEMATODA	12	21	2	10	2

BATTLE RIVER - AT HWY 53
00AL05FA0280

May 9, 1989

ANNELIDA					
HIRUDINEA					
PHARYNGOBDELLIDA					
Erpobdellidae	0	0	0	1	0
Erpobdella punctata	0	0	1	0	0
Nephelopsis	2	0	0	0	0
RHYNCHOBDELLIDA					
Glossiphonidae					
Glossiphonia complanata	0	0	2	1	0
Helobdella stagnalis	1	0	1	3	0
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	0	0	0	0	1
Naididae	0	1	1	2	0
Tubificidae	30	33	94	9	88
ARTHROPODA					
CRUSTACEA					
COPEPODA					
Cyclopoida	1	7	0	1	3
MALACOSTRACA					
Amphipoda					
Gammarus lacustris	0	0	6	5	0
Hyalella azteca	13	0	10	2	4
INSECTA					
COLEOPTERA					
Elmidae					
Dubiraphia	0	0	2	0	0
DIPTERA					
Ceratopogonidae	1	1	1	0	0
Chironomidae					
Chironomini	0	4	21	0	6
Tanypodinae	7	2	5	1	1
Tanytarsini	0	1	7	1	0
EPHEMEROPTERA					
Caenidae					
Caenis	0	0	5	1	0
TRICHOPTERA					
Limnephilidae					
Psychoglypha	0	0	1	0	0
MOLLUSCA					
GASTROPODA					
PROSOBRANCHIA					
Valvatidae					
Valvata	0	1	0	0	1
PELECYPODA					
BIVALVIA					
Sphaeriidae	35	60	28	27	13
Pisidium	1	0	1	1	3
Sphaerium	0	0	1	0	0
NEMATODA	0	5	38	1	22

BATTLE RIVER - AT HWY 53
00AL05FA0280

Oct. 13, 1989

ANNELIDA					
HIRUDINEA					
PHARYNGOBDELLIDA					
Erpobdellidae	4	3	0	1	2
Nephelopsis	1	4	0	0	3
RHYNCHOBDELLIDA					
Glossiphonidae					
Glossiphonia complanata	1	0	0	0	3
Helobdella stagnalis	0	1	0	0	1
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	1	0	0	0	0
Naididae	3	1	2	2	5
Tubificidae	6	8	4	9	10
ARTHROPODA					
ARACHNOIDA					
ACARI	0	1	0	0	0
CRUSTACEA					
CLADOCERA					
Daphniidae					
Daphnia	0	8	0	0	0
Chydoridae					
Leydigia	0	1	0	0	0
Macrothricidae					
Ilyocryptus	0	0	0	1	0
Macrothrix	1	0	0	0	0
COPEPODA					
Cyclopoida	7	68	0	20	5
MALACOSTRACA					
Amphipoda					
Gammarus lacustris	52	33	14	6	24
Hyalella azteca	332	304	25	148	211
OSTRACODA	0	2	0	0	0
INSECTA					
COLEOPTERA					
Elmidae	0	1	0	0	0
Dubiraphia	6	4	0	5	4
Optioservus	1	2	0	0	0
DIPTERA					
Ceratopogonidae	3	1	0	6	19
Chironomidae					
Chironomini	668	1079	87	1161	489
Diamesinae	0	0	0	7	0
Orthocladiinae	340	1326	141	348	288
Tanypodinae	24	131	0	38	8
Tanytarsini	1146	4790	797	3343	1102
Simuliidae					
Simulium	347	21	811	18	854
Tabanidae					
Chrysops	0	0	0	1	0
Tipulidae	0	1	0	1	0
EPHEMEROPTERA	1	0	0	0	0
Baetidae	0	1	0	1	3
Caenidae					
Caenis	6	5	3	2	3
Heptageniidae	1	1	0	0	0
Leptophlebiidae	1	0	0	0	0
Leptophlebia	1	6	0	1	0
ODONATA					
Coenagrionidae					
Enallagma	0	1	0	0	0
TRICHOPTERA					
Hydropsychidae	0	0	1	0	0
Hydropsyche	0	0	2	0	0
Leptoceridae					
Ceraclea	1	12	0	1	1
Oecetis	0	1	0	0	1
Limnephilidae					
Limnephilus	0	0	0	0	1
Nemotaulius	0	1	0	0	0
Phryganeidae					
Ptilostomis	0	0	1	0	0
COELENTERATA					
HYDROZOA					
HYDROIDEA					
Hydridae					
Hydra	0	0	0	8	0
MOLLUSCA					
PELECYPODA					
BIVALVIA					
Sphaeriidae	0	1	0	2	6
Pisidium	1	5	0	6	3
NEMATODA	0	2	0	7	4

BATTLE RIVER - D/S PONOKA, NR HWY 2A
00AL05FA0413

May 5, 1989

ANNELIDA					
HIRUDINEA					
PHARYNGOBDELLIDA					
Erpobdellidae	0	4	8	4	0
Nephelopsis	0	1	1	0	1
RHYNCHOBDELLIDA					
Glossiphonidae					
Glossiphonia complanata	0	3	0	0	0
Helobdella stagnalis	6	18	5	9	6
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	1	1	1	0	1
Naididae	3	6	7	3	8
Tubificidae	307	424	313	501	284
ARTHROPODA					
CRUSTACEA					
MALACOSTRACA					
Amphipoda					
Gammarus lacustris	0	29	2	4	0
Hyalella azteca	42	275	134	209	105
OSTRACODA	7	0	0	0	1
INSECTA					
COLEOPTERA					
Elmidae					
Dubiraphia	1	0	0	0	1
Haliplidae					
Haliplus	1	0	0	0	0
DIPTERA					
Ceratopogonidae	0	0	0	0	1
Chironomidae					
Chironomini	3	9	5	9	20
Orthocladiinae	0	2	2	4	0
Tanypodinae	3	2	2	1	1
Tanytarsini	3	2	2	2	1
EPHEMEROPTERA					
Caenidae					
Caenis	8	3	3	2	1
TRICHOPTERA					
Leptoceridae					
Ceraclea	0	0	1	0	1
Oecetis	0	0	0	1	0
Limnephilidae					
Nemotaulius	0	0	1	0	0
Polycentropodidae					
Polycentropus	0	0	0	0	2
MOLLUSCA					
PELECYPODA					
BIVALVIA					
Sphaeriidae	101	1	3	13	22
Pisidium	41	7	10	11	2
Sphaerium	0	0	0	1	0
Unionidae					
Anodontinae	0	0	0	0	1
NEMATODA	11	4	0	3	9

BATTLE RIVER - D/S PONOKA, NR HWY 2A
00AL05FA0413

Oct. 7, 1989

ANNELIDA					
HIRUDINEA					
PHARYNGOBDELLIDA					
Erpobdellidae	3	0	0	0	0
Erpobdella punctata	0	2	0	0	0
Nephelopsis	0	0	0	2	2
RHYNCHOBDELLIDA					
Glossiphonidae					
Glossiphonia complanata	0	3	1	0	1
Helobdella stagnalis	2	0	0	0	0
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	0	0	0	7	4
Naididae	2	5	1	47	0
Tubificidae	2	128	145	566	241
ARTHROPODA					
CRUSTACEA					
COPEPODA					
Cyclopoida	9	3	1	11	26
MALACOSTRACA					
Amphipoda					
Gammarus lacustris	32	37	33	18	59
Hyalella azteca	214	67	97	165	206
OSTRACODA	0	1	0	0	0
INSECTA					
COLEOPTERA					
Chrysomelidae					
Donacia	0	1	0	1	0
Elmidae	2	2	2	1	1
Dubiraphia	1	2	2	1	3
DIPTERA					
Ceratopogonidae	0	1	8	14	5
Chironomidae					
Chironomini	13	72	360	1500	22
Diamesinae	0	0	0	1	0
Orthocladiinae	2	2	11	47	0
Tanypodinae	4	4	6	13	2
Tanytarsini	28	13	56	102	2
Tabanidae					
Chrysops	0	0	0	0	3
Tipulidae					
Limnophila	0	0	0	2	0
EPHEMEROPTERA					
Caenidae					
Caenis	5	0	1	4	0
Ephemeridae					
Hexagenia	0	0	0	0	1
ODONATA					
Coenagrionidae					
Enallagma	6	1	1	0	1
TRICHOPTERA					
Leptoceridae					
Ceraclea	1	0	0	0	0
Oecetis	0	0	0	1	0
Polycentropodidae					
Polycentropus	1	0	0	1	0
COELENTERATA					
HYDROZOA					
HYDROIDEA					
Hydridae					
Hydra	0	0	0	4	0
MOLLUSCA					
GASTROPODA	0	0	1	0	1
PROSOBRANCHIA					
Valvatidae					
Valvata	0	0	0	2	7
PELECYPODA					
BIVALVIA					
Sphaeriidae	4	0	0	6	73
Pisidium	7	1	1	0	41
Unionidae					
Anodontinae	0	0	0	0	1
NEMATODA	0	3	1	4	15

BATTLE RIVER - D/S SAMSON LAKE, HWY 611

00AL05FA0500

May 9, 1989

ANNELIDA					
HIRUDINEA					
PHARYNGOBDELLIDA					
Erpobdellidae					
Nephelopsis	0	0	0	0	2
RHYNCHOBDELLIDA					
Glossiphonidae					
Helobdella stagnalis	0	0	0	0	1
OLIGOCHAETA					
HAPLOTAXIDA					
Naididae	6	23	9	2	11
Tubificidae	25	15	12	5	140
ARTHROPODA					
CRUSTACEA					
COPEPODA					
Cyclopoida	6	2	1	0	7
MALACOSTRACA					
Amphipoda					
Hyalella azteca	0	0	0	1	0
OSTRACODA	167	10	22	51	71
INSECTA					
DIPTERA					
Ceratopogonidae	0	1	0	0	0
Chironomidae	2	1	1	0	1
Chironomini	47	73	45	15	45
Orthocladiinae	5	3	5	0	0
Tanypodinae	0	0	1	2	1
Tanytarsini	51	274	121	9	25
EPHEMEROPTERA					
Caenidae					
Caenis	1	0	1	1	5
TRICHOPTERA					
Limnephilidae					
Psychoglypha	0	0	0	0	3
MOLLUSCA					
PELECYPODA					
BIVALVIA					
Sphaeriidae	6	0	1	3	0
NEMATODA	25	15	10	19	39

BATTLE RIVER - AT HWY 21
00AL05FA0700

May 9, 1989

ANNELIDA					
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	1	1	0	0	0
Naididae	2	3	0	0	1
Tubificidae	99	78	52	153	106
ARTHROPODA					
CRUSTACEA					
COPEPODA					
Cyclopoida	2	1	0	4	2
MALACOSTRACA					
Amphipoda					
Hyalella azteca	1	0	0	0	0
OSTRACODA	19	5	2	1	11
INSECTA					
COLEOPTERA					
Elmidae					
Dubiraphia	0	0	0	0	1
DIPTERA					
Ceratopogonidae	0	1	0	0	0
Chironomidae					
Chironomini	3	12	0	1	3
Orthocladiinae	0	1	0	0	0
Tanytarsini	0	0	0	1	0
Simuliidae					
Simulium	63	1	3	0	8
TRICHOPTERA					
Leptoceridae					
Oecetis	0	0	0	0	1
MOLLUSCA					
GASTROPODA					
PROSOBRANCHIA					
Valvatidae					
Valvata	0	0	1	0	1
PELECYPODA					
BIVALVIA					
Sphaeriidae	17	14	3	7	9
Pisidium	2	0	0	0	2
NEMATODA	3	0	0	0	1

Oct. 12, 1989

ANNELIDA					
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	0	0	2	1	0
Naididae	0	2	4	1	1
Tubificidae	12	31	99	112	8
ARTHROPODA					
CRUSTACEA					
CLADOCERA					
Daphniidae					
Daphnia	0	0	0	1	0
COPEPODA					
Cyclopoida	0	0	0	1	0
MALACOSTRACA					
Amphipoda					
Gammarus lacustris	0	1	1	6	2
Hyalella azteca	25	21	7	9	14
OSTRACODA	2	0	0	0	2
INSECTA					
DIPTERA					
Ceratopogonidae	0	0	0	2	0
Chironomidae					
Chironomini	21	30	94	128	22
Orthocladiinae	2	0	1	3	0
Tanytarsini	11	5	4	21	0
EPHEMEROPTERA					
Caenidae					
Caenis	0	1	1	0	0
TRICHOPTERA					
Hydropsychidae					
Hydropsyche	0	1	0	0	0
COELENTERATA					
HYDROZOA					
HYDROIDEA					
Hydridae					
Hydra	0	0	1	0	0
MOLLUSCA					
GASTROPODA					
PROSOBRANCHIA					
Valvatidae					
Valvata	0	0	0	1	0
PELECYPODA					
BIVALVIA					
Sphaeriidae	2	0	0	0	2
Sphaerium	0	0	1	0	0
NEMATODA	1	1	4	3	0

BATTLE RIVER - D/S CAMROSE CR.
00AL05FA0750

May 10, 1989

ANNELIDA					
HIRUDINEA					
PHARYNGOBDELLIDA					
Erpobdellidae	1	0	0	0	0
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	0	0	0	0	9
Naididae	3	0	0	0	2
Tubificidae	35	254	26	6	79
ARTHROPODA					
CRUSTACEA					
MALACOSTRACA					
Amphipoda					
Gammarus lacustris	2	0	0	0	0
Hyalella azteca	2	4	7	0	16
OSTRACODA	24	30	23	22	37
INSECTA					
COLEOPTERA					
Elmidae					
Dubiraphia	0	0	1	4	1
DIPTERA	0	0	0	0	1
Ceratopogonidae	0	2	4	4	2
Chironomidae	2	7	3	0	2
Chironomini	30	40	62	19	29
Orthocladiinae	0	3	0	0	5
Tanypodinae	5	1	0	0	10
Tanytarsini	0	2	0	0	12
Simuliidae					
Simulium	0	0	0	12	0
MOLLUSCA					
PELECYPODA					
BIVALVIA					
Sphaeriidae	1	0	1	0	0
Pisidium	0	0	2	0	0
NEMATODA	83	358	168	47	54

Oct. 10, 1989

ANNELIDA					
HIRUDINEA					
PHARYNGOBDELLIDA					
Erpobdellidae					
Nephelopsis	0	1	0	0	0
RHYNCHOBDELLIDA					
Glossiphonidae					
Glossiphonia complanata	0	0	1	0	0
Theromyzon	0	1	0	0	0
OLIGOCHAETA					
HAPLOTAXIDA					
Naididae	74	32	24	20	40
Tubificidae	169	268	64	308	450
ARTHROPODA					
CRUSTACEA					
COPEPODA					
Cyclopoida	4	2	6	0	1
MALACOSTRACA					
Amphipoda					
Gammarus lacustris	5	3	19	12	7
Hyalella azteca	4	16	10	8	2
OSTRACODA	1	0	0	1	1
INSECTA					
COLEOPTERA					
Elmidae					
Dubiraphia	0	0	1	0	0
DIPTERA					
Chaoboridae					
Chaoborus	0	1	0	3	6
Chironomidae					
Chironomini	23	25	83	25	20
Orthocladiinae	0	1	2	0	0
Tanypodinae	40	25	94	71	24
Tanytarsini	0	1	3	1	0
ODONATA					
Coenagrionidae					
Enallagma	0	0	1	0	0
MOLLUSCA					
PELECYPODA					
BIVALVIA					
Sphaeriidae	0	1	0	0	1
Pisidium	1	0	0	0	0
NEMATODA	151	164	75	265	85

BATTLE RIVER - AT HWY 850
00AL05FA1000

May 10, 1989

ANNELIDA					
HIRUDINEA					
PHARYNGOBDELLIDA					
Erpobdellidae	2	12	1	7	0
Erpobdella punctata	1	1	0	2	0
Nephelopsis	2	8	3	9	1
RHYNCHOBDELLIDA					
Glossiphonidae					
Glossiphonia complanata	1	2	0	2	0
Helobdella stagnalis	2	1	0	4	0
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	0	0	0	1	1
Naididae	19	2	18	13	6
Tubificidae	74	134	111	359	107
ARTHROPODA					
CRUSTACEA					
COPEPODA					
Cyclopoida	8	12	12	3	10
MALACOSTRACA					
Amphipoda					
Gammarus lacustris	0	0	0	0	1
Hyalella azteca	3	12	2	25	4
OSTRACODA	1	1	1	1	1
INSECTA					
COLEOPTERA					
Haliplidae					
Haliplus	0	2	0	18	0
DIPTERA					
Ceratopogonidae	4	1	1	2	1
Chaoboridae					
Chaoborus	0	0	0	1	0
Chironomidae					
Chironomini	56	8	51	15	60
Orthocladiinae	0	0	1	0	1
Tanypodinae	1	0	0	0	0
Tanytarsini	4	0	5	0	3
Simuliidae					
Simulium	0	1	0	2	0
Tabanidae					
Tabanus	0	0	0	1	0
EPHEMEROPTERA					
Caenidae					
Caenis	0	1	0	0	0
TRICHOPTERA					
Molannidae					
Molanna	0	0	0	1	0
MOLLUSCA					
PELECYPODA					
BIVALVIA					
Sphaeriidae	2	0	1	2	0
Pisidium	0	2	1	4	0
NEMATODA	55	14	14	23	23

BATTLE RIVER - AT HWY 850

00AL05FA1000

Oct. 12, 1989

ANNELIDA					
HIRUDINEA					
PHARYNGOBDELLIDA					
Erpobdellidae	0	9	54	39	7
Erpobdella punctata	0	0	1	2	2
Nephelopsis	4	6	15	9	2
RHYNCHOBDELLIDA					
Glossiphonidae					
Glossiphonia complanata	1	1	3	4	0
Helobdella	0	0	0	4	1
Helobdella stagnalis	4	5	27	26	6
Theromyzon	0	0	0	1	0
OLIGOCHAETA					
HAPLOTAXIDA					
Naididae	80	102	171	276	148
Tubificidae	374	331	893	2170	591
ARTHROPODA					
ARACHNOIDA					
ACARI	0	0	0	1	0
CRUSTACEA					
CLADOCERA					
Daphniidae					
Daphnia	0	0	0	1	0
Chydoridae					
Chydorus	0	0	1	1	0
COPEPODA					
Cyclopoida	32	380	725	49	8
Harpacticoida	2	15	52	0	3
MALACOSTRACA					
Amphipoda					
Gammarus lacustris	35	43	31	50	8
Hyalella azteca	47	383	223	407	150
OSTRACODA	0	0	1	0	0
INSECTA					
COLEOPTERA					
Dytiscidae	0	0	0	0	1
Haliplidae					
Haliplus	0	1	1	1	0
DIPTERA					
Ceratopogonidae	0	0	2	1	1
Chironomidae					
Chironomini	5	3	11	6	9
Orthocladiinae	4	4	2	2	1
Tanypodinae	6	8	0	1	16
Tanytarsini	1	5	1	0	3
Tabanidae					
Chrysops	0	0	0	0	2
EPHEMEROPTERA					
Baetidae					
Callibaetis	0	0	0	1	0
Caenidae					
Caenis	7	3	3	9	3
HEMIPTERA					
Corixidae					
Corisella	0	0	1	0	0
ODONATA					
Coenagrionidae					
Enallagma	9	4	22	23	2
TRICHOPTERA					
Leptoceridae					
Mystacides	0	0	0	0	1
Molannidae					
Molanna	0	0	1	4	0
COELENTERATA					
HYDROZOA					
HYDROIDEA					
Hydridae					
Hydra	7	14	19	0	19
MOLLUSCA					
GASTROPODA	0	0	0	1	0
PULMONATA					
Lymnaeidae					
Lymnaea	0	3	1	1	0
Physidae					
Physa	0	3	2	3	1
Planorbidae					
Promenetus	0	0	2	0	0
PELECYPODA					
BIVALVIA					
Sphaeriidae	30	17	5	7	23
Pisidium	10	1	11	11	31
NEMATODA	54	2	42	72	13

BATTLE RIVER - BIGKNIFE PROV. PARK, U/S FORESTBURG RESERVOIR
00AL05FC0660

May 10, 1989

ANNELIDA					
HIRUDINEA					
PHARYNGOBDELLIDA					
Erpobdellidae					
Erpobdella punctata	1	0	0	1	1
RHYNCHOBDELLIDA					
Glossiphonidae					
Glossiphonia complanata	0	0	2	2	2
Helobdella stagnalis	1	2	6	1	2
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	0	1	0	0	0
Naididae	65	47	21	62	12
Tubificidae	140	91	135	264	127
ARTHROPODA					
CRUSTACEA					
CLADOCERA					
Daphniidae					
Daphnia	1	0	2	1	0
COPEPODA					
Cyclopoida	19	11	44	19	9
MALACOSTRACA					
Amphipoda					
Gammarus lacustris	0	0	0	0	5
Hyalella azteca	28	28	28	47	42
OSTRACODA	24	27	46	41	30
INSECTA					
DIPTERA					
Ceratopogonidae	2	0	1	0	1
Chaoboridae					
Chaoborus	1	0	0	0	1
Chironomidae	0	0	0	1	0
Chironomini	41	20	67	77	89
Orthocladiinae	0	0	1	8	4
Tanypodinae	1	2	6	6	5
Tanytarsini	2	0	0	1	2
EPHEMEROPTERA					
Caenidae					
Caenis	0	0	0	1	0
LEPIDOPTERA	0	0	0	0	2
ODONATA					
Coenagrionidae					
Enallagma	0	0	0	4	5
Corduliidae					
Cordulia	0	0	1	0	0
TRICHOPTERA					
Leptoceridae					
Triaenodes	0	0	0	0	1

MOLLUSCA					
GASTROPODA					
CTENOBRANCHIATA					
Valvatidae					
Valvata	5	3	4	207	32
PULMONATA					
Planorbidae					
Planorbula	0	0	0	1	0
Promenetus	0	0	0	1	0
PELECYPODA					
BIVALVIA					
Sphaeriidae	1	0	4	18	2
Pisidium	1	0	0	6	2
Sphaerium	0	0	0	1	0
NEMATODA	75	129	101	57	82

BATTLE RIVER - HWY 861, D/S FORESTBURG RESERVOIR
00AL05FC0680

May 10, 1989

ANNELIDA					
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	1	0	0	0	0
Naididae	0	1	1	0	1
Tubificidae	49	12	1	32	45
ARTHROPODA					
CRUSTACEA					
COPEPODA					
Cyclopoida	0	0	1	0	0
MALACOSTRACA					
Amphipoda					
Gammarus lacustris	5	2	1	14	61
Hyalella azteca	3	1	0	5	11
OSTRACODA	1	0	1	1	1
INSECTA					
DIPTERA	0	1	0	0	0
Ceratopogonidae	0	0	0	0	1
Chaoboridae					
Chaoborus	0	1	0	0	1
Chironomidae					
Chironomini	4	1	0	14	8
Tanytarsini	2	0	0	2	0
COELENTERATA					
HYDROZOA					
HYDROIDEA					
Hydridae					
Hydra	4	3	2	7	0
MOLLUSCA					
GASTROPODA	1	0	0	0	0
PELECYPODA					
BIVALVIA					
Sphaeriidae	33	0	1	7	10
Pisidium	2	1	0	0	1
Sphaerium	4	0	0	0	3
Unionidae					
Anodontinae	0	0	1	0	0
NEMATODA	2	0	1	1	0

Oct. 11, 1989

ANNELIDA					
HIRUDINEA					
RHYNCHOBDELLIDA					
Glossiphonidae					
Glossiphonia complanata	1	0	0	0	0
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	6	0	0	0	1
Naididae	6	2	9	19	7
Tubificidae	85	141	21	62	50
ARTHROPODA					
CRUSTACEA					
CLADOCERA					
Daphniidae					
Daphnia	5	0	4	0	2
Macrothricidae					
Macrothrix	0	0	0	0	1
COPEPODA					
Cyclopoida	43	33	22	6	65
MALACOSTRACA					
Amphipoda					
Gammarus lacustris	8	20	3	60	4
Hyalella azteca	53	24	12	9	46
OSTRACODA	0	1	1	0	0
INSECTA					
COLEOPTERA					
Elmidae	0	0	1	0	0
Dubiraphia	3	1	0	2	0
Optioservus	0	0	2	0	0
DIPTERA					
Ceratopogonidae	0	1	1	1	3
Chironomidae					
Chironomini	194	74	150	43	161
Orthocladiinae	1	0	9	0	3
Tanypodinae	6	1	5	4	1
Tanytarsini	2	1	52	0	8
EPHEMEROPTERA					
Baetidae					
Callibaetis	0	0	1	0	0
Caenidae					
Caenis	7	2	7	1	4
Ephemeridae					
Hexagenia	2	10	1	2	4
TRICHOPTERA					
Leptoceridae					
Oecetis	0	0	1	0	0
MEGALOPTERA					
Sialidae					
Sialis	1	0	0	0	0
MOLLUSCA					
PELECYPODA					
BIVALVIA					
Sphaeriidae	18	26	9	0	19
Pisidium	2	8	1	0	2
NEMATODA	12	9	2	0	6

BATTLE RIVER - HWY 872, NR BATTLEBEND

00AL05FC1000

May 11, 1989

ANNELIDA					
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	0	0	0	0	3
Naididae	0	0	0	0	5
ARTHROPODA					
CRUSTACEA					
COPEPODA					
Cyclopoida	0	0	0	2	1
MALACOSTRACA					
Amphipoda					
Hyalella azteca	0	0	0	0	17
OSTRACODA	4	3	12	4	20
INSECTA					
COLEOPTERA					
Elmidae					
Dubiraphia	0	0	0	0	3
Narpus	0	0	0	0	1
Haliplidae					
Haliplus	0	0	0	0	16
DIPTERA					
Chironomidae					
Chironomini	0	1	1	6	2
Tanytarsini	0	0	0	1	0
Simuliidae					
Simulium	0	0	0	0	2
EPHEMEROPTERA					
Caenidae					
Caenis	0	0	0	0	13
ODONATA					
Corduliidae					
Cordulia	0	0	0	0	1
TRICHOPTERA					
Leptoceridae					
Ceraclea	0	0	0	0	1
MOLLUSCA					
GASTROPODA	1	1	0	0	0
PULMONATA					
Planorbidae					
Planorbula	1	0	3	1	0
PELECYPODA					
BIVALVIA					
Sphaeriidae	0	1	0	0	2
Pisidium	0	0	0	1	1
Sphaerium	0	0	0	1	0
NEMATODA	0	2	0	0	0

BATTLE RIVER - HWY 872, NR BATTLEBEND

00AL05FC1000

Oct. 11, 1989

ANNELIDA					
HIRUDINEA					
RHYNCHOBDELLIDA					
Glossiphonidae					
Theromyzon	0	0	0	0	1
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	1	8	0	20	1
Naididae	8	11	22	22	6
Tubificidae	3	21	38	25	10
ARTHROPODA					
ARACHNOIDA					
ACARI	1	0	0	0	0
CRUSTACEA					
CLADOCERA					
Daphniidae					
Ceriodaphnia	21	10	7	52	4
Chydoridae					
Chydorus	0	0	1	0	0
Leycigia	0	0	3	6	0
Macrothricidae					
Ilyocryptus	0	0	0	1	0
Macrothrix	0	0	0	4	0
COPEPODA					
Cyclopoida	15	32	43	195	25
MALACOSTRACA					
Amphipoda					
Gammarus lacustris	0	0	1	3	0
Hyalella azteca	18	32	64	51	39
OSTRACODA	8	11	41	14	29
INSECTA					
COLEOPTERA					
Elmidae	0	2	0	0	0
Dubiraphia	1	3	1	1	0
DIPTERA					
Ceratopogonidae	51	9	18	42	8
Chironomidae					
Chironomini	425	1045	1655	623	2619
Orthocladiinae	16	60	107	109	60
Tanypodinae	54	335	235	602	40
Tanytarsini	242	978	1662	397	703
EPHEMEROPTERA					
Baetidae					
Callibaetis	2	3	1	1	1
Caenidae					
Caenis	4	2	6	6	0
Ephemeridae					
Hexagenia	0	1	4	3	2
Heptageniidae					
Stenonema	0	1	0	5	0
Leptophlebiidae	0	0	0	1	0
Leptophlebia	0	1	1	0	0
HEMIPTERA					
Corixidae					
Corisella	0	1	0	1	0
ODONATA					
Gomphidae					
Cphiogomphus	0	0	0	0	1
TRICHOPTERA					
Hydropsychidae					
Hydropsyche	1	0	0	1	0
Leptoceridae					
Oecetis	3	1	0	0	0
Polycentropodidae					
Neureclipsis	0	0	0	0	1
Polycentropus	9	20	2	9	0
MEGALOPTERA					
Sialidae					
Sialis	0	0	0	1	0
MOLLUSCA					
PELECYPODA					
BIVALVIA					
Sphaeriidae	6	2	12	4	4
Pisidium	0	1	1	2	0
Sphaerium	2	0	4	8	5
NEMATODA	6	3	6	7	5

BATTLE RIVER - D/S HARDISTY

00AL05FB0501

Oct. 11, 1989

ANNELIDA					
HIRUDINEA					
PHARYNGOBDELLIDA					
Erpobdellidae					
Erpobdella punctata	0	0	0	1	0
RHYNCHOBDELLIDA					
Glossiphonidae					
Helobdella stagnalis	0	1	0	1	0
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	0	0	1	4	0
Naididae	35	32	11	736	111
Tubificidae	37	44	90	1441	522
ARTHROPODA					
CRUSTACEA					
CLADOCERA					
Daphniidae					
Ceriodaphnia	4	11	12	5	2
Daphnia	0	9	1	0	0
Chydoridae					
Leydigia	1	4	0	1	0
Pleuroxus denticulatus	0	1	0	0	0
Macrothricidae					
Ilyocryptus	0	1	0	0	0
COPEPODA					
Cyclopoida	15	61	19	16	18
MALACOSTRACA					
Amphipoda					
Hyalella azteca	28	8	10	1	1
OSTRACODA	79	456	84	8	9
INSECTA					
COLEOPTERA					
Elmidae					
Dubiraphia	2	0	3	6	2
COLLEMBOLA	0	1	0	0	0
DIPTERA					
Ceratopogonidae	16	26	5	8	7
Chironomidae					
Chironomini	27	200	34	83	949
Orthocladiinae	18	20	5	3	40
Tanypodinae	49	160	89	22	65
Tanytarsini	9	12	5	5	36
EPHEMEROPTERA					
Baetidae	0	0	1	0	1
Callibaetis	16	23	10	2	1
Caenidae					
Caenis	3	2	1	3	1
Ephemeridae					
Hexagenia	3	2	0	0	0
HEMIPTERA					
Corixidae	7	12	2	1	0
Corisella	4	8	1	0	0
ODONATA					
Coenagrionidae					
Enallagma	2	0	1	0	0
TRICHOPTERA					
Leptoceridae					
Oecetis	0	2	0	0	0
Polycentropodidae					
Polycentropus	8	9	50	26	13
MEGALOPTERA					
Sialidae					
Sialis	1	0	2	0	0
COELENTERATA					
HYDROZOA					
HYDROIDEA					
Hydridae					
Hydra	1	0	0	0	0
MOLLUSCA					
PELECYPODA					
BIVALVIA					
Sphaeriidae	0	1	0	0	0
NEMATODA	8	76	1	1	0

BATTLE RIVER - D/S HARDISTY
00AL05FB0501

May 11, 1989

ANNELIDA					
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	1	0	0	1	0
Naididae	1	1	4	15	13
Tubificidae	0	5	4	10	4
ARTHROPODA					
CRUSTACEA					
COPEPODA					
Cyclopoida	9	2	6	8	13
MALACOSTRACA					
Amphipoda					
Hyalella azteca	0	0	0	1	1
INSECTA					
COLEOPTERA					
Elmidae					
Dubiraphia	1	0	0	1	2
Haliplidae					
Haliplus	0	0	0	2	0
DIPTERA					
Ceratopogonidae	0	0	4	10	6
Chironomidae	0	0	0	2	2
Chironomini	9	16	60	110	174
Tanypodinae	0	0	0	0	1
Tanytarsini	17	4	131	527	376
Simuliidae					
Simulium	0	0	0	0	122
EPHEMEROPTERA					
Caenidae					
Caenis	0	0	0	0	6
ODONATA					
Coenagrionidae					
Enallagma	0	0	0	0	1
TRICHOPTERA					
Leptoceridae					
Oecetis	0	0	2	1	3
MOLLUSCA					
GASTROPODA					
PULMONATA					
Planorbidae					
Planorbula	1	0	0	0	0
PELECYPODA					
BIVALVIA					
Sphaeriidae	0	0	0	1	0
Sphaerium	1	2	9	4	0
NEMATODA	5	1	1	1	14

BATTLE RIVER - AT HWY 41
00AL05FE0400

May 17, 1989

ANNELIDA					
HIRUDINEA					
RHYNCHOBDELLIDA					
Glossiphonidae					
Helobdella stagnalis	0	0	0	1	0
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	0	0	2	2	0
Naididae	0	0	1	12	0
Tubificidae	1	0	4	100	1
ARTHROPODA					
CRUSTACEA					
COPEPODA					
Cyclopoida	0	3	1	0	5
MALACOSTRACA					
Amphipoda					
Hyalella azteca	1	0	0	39	0
OSTRACODA	0	2	0	24	0
INSECTA					
COLEOPTERA					
Elmidae					
Dubiraphia	0	0	0	6	0
DIPTERA					
Chironomidae					
Chironomini	5	4	6	11	1
Orthocladiinae	0	0	0	5	2
Tanytarsini	0	0	17	2	0
Simuliidae					
Simulium	0	0	2	5	8
Tabanidae					
Chrysops	0	0	0	1	0
ODONATA					
Coenagrionidae					
Enallagma	0	0	0	1	0
TRICHOPTERA					
Leptoceridae					
Oecetis	0	0	1	0	0
MOLLUSCA					
GASTROPODA					
PULMONATA					
Planorbidae					
Planorbula	0	0	0	4	0
PELECYPODA					
BIVALVIA					
Sphaeriidae	1	0	0	4	0
Sphaeriidae					
Pisidium	0	0	0	53	0
Sphaerium	0	0	1	0	
NEMATODA	0	2	0	11	0

BATTLE RIVER - AT HWY 41
00AL05FE0400

Oct. 11, 1989

ANNELIDA					
HIRUDINEA					
PHARYNGOBDELLIDA					
Erpobdellidae					
Erpobdella punctata	0	0	0	0	1
RHYNCHOBDELLIDA					
Glossiphonidae					
Helobdella stagnalis	0	0	0	0	5
OLIGOCHAETA					
HAPLOTAXIDA					
Naididae	117	135	222	180	94
Tubificidae	10	18	6	8	10
ARTHROPODA					
ARACHNOIDA					
ACARI	0	1	0	0	0
CRUSTACEA					
CLADOCERA					
Daphniidae					
Daphnia	18	0	0	0	74
Chydoridae					
Leydigia	0	1	0	0	2
COPEPODA					
Cyclopoida	118	48	4	4	222
MALACOSTRACA					
Amphipoda					
Gammarus lacustris	0	0	0	0	1
Hyalella azteca	237	276	132	146	539
OSTRACODA	22	45	42	45	28
INSECTA					
COLEOPTERA					
Elmidae					
Dubiraphia	1	1	1	0	2
DIPTERA					
Ceratopogonidae	2	6	5	13	3
Chironomidae					
Chironomini	115	211	322	234	42
Orthocladiinae	4	7	9	7	12
Tanypodinae	85	263	127	115	132
Tanytarsini	299	511	658	401	418
Tabanidae					
Chrysops	0	0	0	0	1
EPHEMEROPTERA					
Baetidae	0	0	0	0	1
Callibaetis	0	3	0	2	8
Caenidae					
Caenis	4	3	3	4	5
Heptageniidae	0	0	0	0	1
Leptophlebiidae					
Leptophlebia	0	0	0	0	2
Tricorythidae					
Tricorythodes	0	0	0	0	1
HEMIPTERA					
Corixidae					
Corisella	9	4	35	4	0
ODONATA					
Coenagrionidae					
Enallagma	0	0	0	1	1
TRICHOPTERA					
Hydropsychidae	0	1	0	0	0
Hydropsyche	0	1	0	0	0
Leptoceridae					
Oecetis	0	0	3	0	0
Polycentropodidae					
Polycentropus	1	1	0	0	27
COELENTERATA					
HYDROZOA					
HYDROIDEA					
Hydridae					
Hydra	0	1	0	0	0
MOLLUSCA					
GASTROPODA					
PULMONATA					
Physidae					
Physa	0	0	0	0	1
PELECYPODA					
BIVALVIA					
Sphaeriidae	2	8	0	0	2
Pisidium	0	1	0	0	2
Sphaerium	0	4	0	0	0
NEMATODA	1	4	0	1	2

BATTLE RIVER - AT HWY 897
00AL05FE0850

May 17, 1989

ANNELIDA					
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	0	0	0	0	10
Tubificidae	1	5	0	0	152
ARTHROPODA					
CRUSTACEA					
CLADOCERA					
Chydoridae	1	0	0	0	0
COPEPODA					
Cyclopoida	6	0	0	2	0
MALACOSTRACA					
Amphipoda					
Gammarus lacustris	0	0	0	0	6
Hyalella azteca	0	0	1	0	42
OSTRACODA	1	5	3	2	0
INSECTA					
COLEOPTERA					
Elmidae					
Dubiraphia	0	0	0	0	1
DIPTERA					
Chironomidae					
Chironomini	0	3	2	0	18
Tanytarsini	0	2	0	0	2
Simuliidae					
Simulium	1	1	0	0	5
EPHEMEROPTERA	0	0	1	0	0
Baetidae	1	0	0	0	0
MOLLUSCA					
PELECYPODA					
BIVALVIA					
Sphaeriidae	1	0	0	0	0
NEMATODA	0	1	1	0	8

Oct. 11, 1989

ANNELIDA					
OLIGOCHAETA					
HAPLOTAXIDA					
Naididae	3	14	1	0	0
Tubificidae	2	16	1	1	0
ARTHROPODA					
CRUSTACEA					
COPEPODA					
Cyclopoida	102	3	0	0	0
Harpacticoida	0	1	0	0	0
MALACOSTRACA					
Amphipoda					
Gammarus lacustris	2	1	1	1	1
Hyalella azteca	64	128	50	63	16
OSTRACODA	6	10	1	0	1
INSECTA					
COLLEMBOLA	2	0	0	0	0
DIPTERA					
Ceratopogonidae	0	2	1	2	1
Chironomidae					
Chironomini	126	41	15	12	7
Orthocladiinae	17	50	13	18	14
Tanypodinae	4	10	2	0	0
Tanytarsini	117	202	85	118	47
Simuliidae					
Simulium	1	1	0	0	0
EPHEMEROPTERA					
Saetidae	0	0	0	0	1
PLECOPTERA					
Perlodidae	0	1	0	1	0
TRICHOPTERA					
Leptoceridae					
Nectopsyche	0	0	0	0	1
Oecetis	0	2	0	1	1
MOLLUSCA					
GASTROPODA					
PULMONATA					
Physidae					
Physa	0	0	0	0	1
PELECYPODA					
BIVALVIA					
Sphaeriidae	0	1	0	1	0
NEMATODA	6	3	0	0	0

BATTLE RIVER - NR UNWIN
00SA05FE1000

May 17, 1989

ANNELIDA					
OLIGOCHAETA					
HAPLOTAXIDA					
Tubificidae	1	0	0	0	1
ARTHROPODA					
CRUSTACEA					
MALACOSTRACA					
Amphipoda					
Hyalella azteca	0	1	0	1	0
Gammarus lacustris	0	1	1	0	0
INSECTA					
COLEOPTERA					
Elmidae					
Dubiraphia	0	1	0	0	0
Optioservus	0	0	0	0	1
DIPTERA					
Ceratopogonidae	0	2	6	1	5
Chaoboridae					
Chaoborus	0	0	1	0	0
Chironomidae					
Chironomini	5	3	4	14	5
MOLLUSCA					
PELECYPODA					
BIVALVIA					
Sphaeriidae	0	1	0	0	0
Sphaerium	7	0	2	0	0

Oct. 3, 1989

ANNELIDA					
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	0	0	1	0	0
Tubificidae	0	3	10	1	5
ARTHROPODA					
CRUSTACEA					
CLADOCERA					
Bosminidae					
Bosmina	0	0	1	0	0
COPEPODA					
Cyclopoida	1	1	1	0	1
MALACOSTRACA					
Amphipoda					
Hyalella azteca	0	0	14	1	0
OSTRACODA	0	0	19	21	2
INSECTA					
DIPTERA					
Chironomidae					
Chironomini	3	1	2	0	6
Tanypodinae	0	0	2	0	0
Tanytarsini	0	1	1	0	0
Simuliidae					
Simulium	0	0	8	0	0
EPHEMEROPTERA					
Leptophlebiidae					
Paraleptophlebia	0	0	0	1	0
MOLLUSCA					
PELECYPODA					
BIVALVIA					
Sphaeriidae	0	0	0	1	0
Pisidium	0	0	1	1	0
NEMATODA	1	0	1	0	0

BATTLE RIVER - AT HWY 40, U/S BATTLEFORD
00SA05FF1000

May 17, 1989

ANNELIDA					
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	0	0	0	0	2
Naididae	0	0	7	0	10
Tubificidae	0	0	3	0	19
ARTHROPODA					
CRUSTACEA					
CLADOCERA					
Daphniidae					
Daphnia	4	0	0	0	0
Bosminidae					
Bosmina	4	0	4	9	0
Chydoridae	2	0	1	1	0
COPEPODA					
Cyclopoida	24	0	15	21	0
Calanoida	1	0	0	0	0
MALACOSTRACA					
Amphipoda					
Hyalella azteca	0	0	1	0	53
OSTRACODA	1	0	4	1	6
INSECTA					
DIPTERA					
Ceratopogonidae	0	0	0	0	1
Chironomidae					
Chironomini	4	0	7	2	5
Tanypodinae	0	0	0	0	3
Tanytarsini	0	0	2	1	0
Simuliidae					
Simulium	1	0	0	4	43
EPHEMEROPTERA	1	0	0	2	0
Caenidae					
Caenis	0	0	0	0	1
TRICHOPTERA					
Leptoceridae					
Ceraclea	0	0	0	0	1
Oecetis	0	0	0	0	3
Polycentropodidae					
Polycentropus	0	0	0	0	1
COELENTERATA					
HYDROZOA					
HYDROIDEA					
Hydridae					
Hydra	0	0	0	0	2
MOLLUSCA					
PELECYPODA					
BIVALVIA					
Sphaeriidae	1	0	0	0	10
Pisidium	0	1	0	0	15
Sphaerium	0	0	3	0	0
NEMATODA	0	0	2	0	3

Oct. 4, 1989

ANNELIDA					
OLIGOCHAETA					
HAPLOTAXIDA					
Enchytraeidae	3	0	0	0	0
Naididae	43	34	7	41	144
Tubificidae	6	0	0	0	5
ARTHROPODA					
ARACHNOIDA					
ACARI	2	4	1	10	21
CRUSTACEA					
COPEPODA					
Cyclopoida	7	6	2	2	0
MALACOSTRACA					
Amphipoda					
Hyalella azteca	66	2	1	2	54
OSTRACODA	2	0	5	1	6
INSECTA					
COLEOPTERA					
Dytiscidae	0	0	0	1	0
COLLEMBOLA	0	1	0	0	2
DIPTERA					
Ceratopogonidae	2	0	0	0	0
Chaoboridae					
Chaoborus	1	0	0	0	0
Chironomidae					
Chironomini	497	573	704	549	45
Orthocladiinae	8	53	47	54	28
Tanypodinae	24	2	1	5	25
Tanytarsini	141	28	8	12	315
Simuliidae					
Simulium	0	1	0	0	0
EPHEMEROPTERA					
Caenidae					
Caenis	0	0	0	0	1
ODONATA					
Gomphidae					
Gomphus	1	0	0	0	0
PLECOPTERA					
Perlodidae					
Isoperla	0	2	2	1	0
TRICHOPTERA					
Brachycentridae					
Brachycentrus	0	0	0	0	1
Hydropsychidae					
Hydropsyche	0	1	0	0	0
Leptoceridae					
Oecetis	1	0	0	2	7
MOLLUSCA					
PELECYPODA					
BIVALVIA					
Sphaeriidae	1	0	3	0	3
Sphaerium	0	0	0	0	1
NEMATODA	1	0	0	0	0

Appendix 5. Summary of water quality data at the long-term monitoring station at Unwin (Saskatchewan)

NAQUADAT SUMMARY REPORT AUG 23, 1991
SURFACE WATER DATA

STATION 00SA05FE0001 LAT. 52D 56M LONG. 109D 52M PR 7 UTM 12 576000E 5866000N FOR FEB 05, 1974 TO SEP 19, 1990
BATTLE RIVER NEAR UNWIN, SASKATCHEWAN

	SUBM ID	00201L TOTAL DISSOLVED SOLIDS (CALCD.) MG/L	02001L ODOUR THRESHOLD NUMBER TON	02011L COLOUR APPARENT REL. UNITS	02021L COLOUR TRUE REL. UNITS	02041F SPECIFIC CONDUCT. US/CM	02041L SPECIFIC CONDUCT. US/CM	02061F TEMPERATURE OF WATER DEG.C	02073L TURBIDITY JTU
SAMPLES(FLAGS)	0001	194(1)	8(0)	87(2)	113(0)	184(0)	198(0)	200(1)	199(0)
LOW	0060	108.	1.	L5.	10.	304.	183.	-1.5	1.0
HIGH	0462	1267.	2.	200.	200.	2380.	1890.0	29.0	550.0
AVERAGE		575.*	1.	49.*	45.	929.2	925.4	8.0*	29.6
STD.DEV.		187.*	0.	40.*	28.	304.0	289.9	8.3*	65.5
PERCNT:10TH		346.		10.	20.	572.	558.	.0	3.0
25TH		426.	1.	20.	30.	701.0	701.	.0	4.9
MEDIAN 50TH		561.	1.	35.	40.	908.0	903.5	5.3	8.0
75TH		697.	2.	70.	55.	1104.5	1128.	16.0	22.
90TH		820.		100.	70.	1325.	1312.	19.9	80.
SECONDARY CODE						41S		61S	73F 81L

	SUBM ID	05105L BORON DISSOLVED B MG/L	06001L CARBON TOTAL ORGANIC C MG/L	06002L CARBON TOTAL ORGANIC (CALCD.) C MG/L	06051L CARBON TOTAL INORGANIC C MG/L	06101L CARBON DISSOLVED ORGANIC C MG/L	06151L CARBON DISSOLVED INORGANIC C MG/L	06201L BICARBONT. (CALCD.) HCO3 MG/L	06301L CARBONATE (CALCD.) CO3 MG/L
SAMPLES(FLAGS)	0001	171(0)	49(0)	135(1)	49(0)	148(0)	24(0)	187(1)	187(1)
LOW	0060	.020	4.	2.18	26.	2.	34.	99.	0.
HIGH	0462	.40	36.	34.30	166.	19.	146.	980.	26.
AVERAGE		.244	16.06	14.77*	81.	13.	80.	417.*	2.*
STD.DEV.		.074	7.19	4.81*	34.	3.	26.	145.*	5.*
PERCNT:10TH		.150	7.	9.30	37.	9.	42.	250.	0.
25TH		.190	11.	11.46	64.	11.	63.	313.	0.
MEDIAN 50TH		.240	15.	14.54	78.	13.	79.	396.	0.
75TH		.29	19.	17.15	95.	14.	93.	494.	1.
90TH		.35	28.	20.52	128.	16.	108.	Q608.	10.
SECONDARY CODE		05F				04L 04F	52L		

	SUBM ID	06401L FREE CO2 (CALCD.) MG/L	06500L HYDROCARBONS (ALKANES) MG/L	06510L AROMATIC HYDROC. UG/L	06521L OIL AND GREASE MG/L	06532P PHENOLIC MATERIAL MG/L	06535P PHENOLIC MATERIAL PHENOL MG/L	06604L CYANIDE TOTAL CN MG/L	06711L CHLORO - PHYLL A MG/L
SAMPLES(FLAGS)	0001	197(0)	57(57)	59(59)	87(77)	28(7)	161(17)	186(22)	79(26)
LOW	0060	.51	L1.	L1.	L1.	L.002	L.001	L.001	L.001
HIGH	0462	42.98	L1.	L1.	7.	.040	.012	.054	.040
AVERAGE		9.55			1.*	.011*	.003*	.006*	.006*
STD.DEV.		10.96			1.*	.010*	.002*	.006*	.006*
PERCNT:10TH		1.66	L1.	L1.	L1.	L.002	L.001	.002	L.001
25TH		2.42	L1.	L1.	L1.	.004	.001	.003	.001
MEDIAN 50TH		3.75	L1.	L1.	L1.	.007	.002	L.005	L.005
75TH		13.74	L1.	L1.	L1.	.013	.003	.006	.007
90TH		28.88	L1.	L1.	1.	.025	.005	.011	.014
SECONDARY CODE			00P 00F	10P 10F	21P 21F		35F 35L	04P 04F	11F

* THESE STATISTICS INCLUDE VALUES FLAGGED WITH L,G OR Q

NAQUADAT SUMMARY REPORT AUG 23, 1991
SURFACE WATER DATA

STATION 00SA05FE0001 LAT. 52D 56M LONG. 109D 52M PR 7 UTM 12 576000E 5866000N FOR FEB 14, 1974 TO SEP 19, 1990
BATTLE RIVER NEAR UNWIN, SASKATCHEWAN

	SUBM ID	06717L CHLORO-PHYLL A	06901L CARBON ORGANIC PARTICUL.	07001L NITROGEN TOTAL KJELDAHL	07106L NITROGEN DISSOLVED NO3 & NO2	07503L NITROGEN TOTAL AMMONIA	07602L NITROGEN TOTAL (CALCD.)	07603L NITROGEN TOTAL (CALCD.)	07651L NITROGEN DISSOLVED
		C	C	N	N	N	N	N	N
		MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L
SAMPLES(FLAGS)	0060	111(13)	157(1)	50(0)	197(98)	74(50)	49(16)	158(2)	175(0)
LOW	0462	L.001	L.01	.3	L.01	L.050	Q.31	.35	.274
HIGH		.081	18.800	2.6	2.60	.610	4.80	4.00	2.000
AVERAGE		.011*	2.299*	1.05	.118*	.144*	1.22*	1.08*	.759
STD.DEV.		.015*	3.368*	.50	.247*	.123*	.75*	.59*	.268
PERCNT:10TH		L.001	.28	.60	L.01	L.050	.64	.56	.470
25TH		.002	.450	.7	L.010	L.1	Q.81	.73	.58
MEDIAN 50TH		.006	1.000	.85	.01	L.100	Q1.01	.96	.700
75TH		.019	2.3	1.2	.170	.140	1.34	1.20	.90
90TH		.030	7.000	1.75	.35	.320	2.28	1.73	1.10
SECONDARY CODE		17F 17P	02L	02L	10L 10F	06L 06F 06P			

	SUBM ID	07651F NITROGEN DISSOLVED	07901L NITROGEN PARTICUL.	07902L NITROGEN PARTICUL.	08101L OXYGEN DISSOLVED DO	08201F OXYGEN BIOCHEM. DEMAND-BOD	09105L FLUORIDE DISSOLVED	10101L ALKALINITY TOTAL	10151L ALKALINITY PHENOL PHTHALEIN
		N	N	N	O2	O2	F	CACO3	CACO3
		MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L
SAMPLES(FLAGS)	0001	54(0)	55(0)	104(2)	194(0)	57(5)	196(1)	197(0)	189(1)
LOW	0060	.440	.037	L.01	.1	.3	L.05	68.	0.
HIGH	0462	1.20	2.300	2.000	16.3	5.4	.38	804.	21.8
AVERAGE		.750	.354	.313*	8.0	2.0*	.22*	345.	1.9*
STD.DEV.		.168	.492	.402*	3.8	1.1*	.06*	121.	4.0*
PERCNT:10TH		.550	.05	.05	1.3	L0.	.15	205.	.0
25TH		.630	.075	.070	6.3	1.	.19	266.	.0
MEDIAN 50TH		.740	.164	.170	8.7	2.	.22	336.	.0
75TH		.86	.388	.350	10.5	2.4	.25	405.	.5
90TH		.970	.930	.88	12.5	3.6	.29	499.	8.5
SECONDARY CODE					01P 01F	01L	08L 06L 17L	06L 11L	

	SUBM ID	10301F PH	10301L PH	10401L RESIDUE NONFILTR.	10501L RESIDUE FIXED NONFILTR.	10602L HARDNESS TOTAL (CALCD.) CACO3	10603L HARDNESS TOTAL CACO3	10701L SURFACT. N-ALKYL SULPHNTS. LAS	10711P NTA NITRILOTRI ACETIC AC. H3NTA
		PH UNITS	PH UNITS	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L
SAMPLES(FLAGS)	0001	194(0)	200(0)	192(2)	180(15)	183(0)	66(0)	90(43)	13(10)
LOW	0060	6.3	7.3	L0.	.6	106.	80.	L.01	L.01
HIGH	0462	12.3	8.9	872.0	750.0	561.	561.	.07	.013
AVERAGE				65.8*	58.6*	259.	266.	.015*	.010*
STD.DEV.				144.6*	132.2*	85.	99.	.010*	.001*
PERCNT:10TH		7.4	7.50	3.	1.0	167.	162.	L.010	L.01
25TH		7.7	7.70	6.0	3.9	196.	191.	L.01	L.01
MEDIAN 50TH		8.2	8.10	13.0	10.0	240.	240.	.010	L.01
75TH		8.4	8.40	39.6	33.6	313.	325.	.02	L.01
90TH		8.6	8.50	167.	144.5	380.	392.	.030	.01
SECONDARY CODE		01S					05L	01P 01F	

* THESE STATISTICS INCLUDE VALUES FLAGGED WITH L,G OR Q

REQUEST 0007 - 0009 PAGE 3 NAQUADAT SUMMARY REPORT AUG 23, 1991
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STATION 00SA05FE0001 LAT. 52D 56M LONG. 109D 52M PR 7 UTM 12 576000E 5866000N FOR FEB 05, 1974 TO SEP 19, 1990
BATTLE RIVER NEAR UNWIN, SASKATCHEWAN

	SUBM ID	11103L SODIUM DISSOLVED NA MG/L	12102L MAGNESIUM DISSOLVED MG MG/L	12101L MAGNESIUM DISSOLVED (CALCD.) MG MG/L	13102L ALUMINUM DISSOLVED AL MG/L	13302L ALUMINUM EXTRBLE. AL MG/L	13305P ALUMINUM EXTRBLE. AL MG/L	14102L SILICA REACTIVE SIO2 MG/L	15103L PHOSPHORUS DISSOLVED P MG/L
SAMPLES(FLAGS)	0001	198(0)	183(0)	98(0)	74(71)	124(35)	57(1)	198(0)	166(0)
LOW	0060	4.5	10.7	6.1	.029	.020	.008	.4	.003
HIGH	0462	246.0	59.3	59.3	L0.	3.430	.82	20.	.245
AVERAGE		114.7	29.0	30.6	.148*	.356*	.067*	8.7	.030
STD.DEV.		43.6	10.0	10.6	.205*	.495*	.122*	5.0	.032
PERCNT:10TH		62.0	16.5	18.6	L.100	L.100	.012	2.5	.010
25TH		80.0	21.6	23.4	L.100	L.100	.017	5.3	.015
MEDIAN 50TH		113.0	29.0	30.0	L.100	.160	.026	7.5	.021
75TH		145.	35.0	36.9	L.100	.370	.063	12.5	.030
90TH		174.	41.8	43.2	L.1	.93	.15	16.6	.055
SECONDARY CODE						02P 02F		05L 08L	03F

	SUBM ID	15256L PHOSPHORUS DISSOLVED ORTHO PO4 P MG/L	15406L PHOSPHORUS TOTAL P MG/L	15465L PHOSPHORUS DISSOLVED PHOSPHATE P MG/L	15901L PHOSPHORUS PARTICULATE (CALCD.) P MG/L	16104L SULFIDE DISSOLVED S MG/L	16304L SULPHATE DISSOLVED SO4 MG/L	17206L CHLORIDE DISSOLVED CL MG/L	17811L HEXACHLORO-BENZENE UG/L
SAMPLES(FLAGS)	0001	106(52)	197(0)	6(0)	166(0)	22(22)	199(0)	197(1)	145(144)
LOW	0060	L.003	.010	.018	-.030	L.05	14.	L.1	L.001
HIGH	0462	.150	.750	.106	.723	L.05	280.7	52.	.001
AVERAGE		.009*	.109	.038	.076		131.3	19.4*	.001*
STD.DEV.		.017*	.133	.034	.119		47.3	10.0*	.000*
PERCNT:10TH		L.003	.025		.008	L.05	71.0	8.2	L.001
25TH		L.003	.034	.021	.017	L.05	92.	11.0	L.001
MEDIAN 50TH		.003	.060	.024	.032	L.05	130.0	18.3	L.001
75TH		.009	.12	.032	.075	L.05	168.	26.	L.001
90TH		.015	.28		.162	L.05	197.5	34.	L.001
SECONDARY CODE		56F	13L 23L			04P	06L		

	SUBM ID	18000L P,P-DDT UG/L	18005L O,P-DDT UG/L	18010L P,P-DDD UG/L	18020L P,P-DDE UG/L	18030L P,P-METHOXY-CHLOR UG/L	18040L HEPTACHLOR UG/L	18045L HEPTACHLOR EPOXIDE UG/L	18050L ALPHA-ENDO-SULFHAN UG/L
SAMPLES(FLAGS)	0462	162(162)	144(144)	162(161)	162(162)	172(172)	162(162)	162(162)	162(162)
LOW		L.001	L.001	L.001	L.001	L.002	L.001	L.002	L.001
HIGH		L.004	L.003	.003	L.001	L.01	L.002	L.002	L.001
AVERAGE				.002*					
STD.DEV.				.000*					
PERCNT:10TH		L.004	L.001	L.002	L.001	L.01	L.001	L.002	L.001
25TH		L.004	L.001	L.002	L.001	L.010	L.001	L.002	L.001
MEDIAN 50TH		L.004	L.001	L.002	L.001	L.010	L.001	L.002	L.001
75TH		L.004	L.001	L.002	L.001	L.010	L.001	L.002	L.001
90TH		L.004	L.001	L.002	L.001	L.010	L.001	L.002	L.001
SECONDARY CODE									

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SURFACE WATER DATA

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BATTLE RIVER NEAR UNWIN, SASKATCHEWAN

		18055L BETA-ENDO-SULFHAN	18060L ALPHA-CHLORDANE	18065L GAMMA-CHLORDANE	18070L GAMMA-BHC (LINDANE)	18075L ALPHA-BHC	18125L MIREX TOTAL	18130L ALDRIN	18140L ENDRIN
	SUBM ID	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
SAMPLES(FLAGS)	0462	162(162)	150(150)	150(150)	172(97)	159(19)	145(145)	162(162)	160(160)
LOW		L.001	L.003	L.002	L.001	L.001	L.001	L.001	L.002
HIGH		L.005	L.003	L.002	.030	.02	L.002	L.001	L.002
AVERAGE					.002*	.0038*			
STD.DEV.					.003*	.0030*			
PERCNT:10TH		L.003	L.003	L.002	L.001	L.001	L.001	L.001	L.002
25TH		L.003	L.003	L.002	L.001	.002	L.001	L.001	L.002
MEDIAN 50TH		L.003	L.003	L.002	L.001	.0030	L.001	L.001	L.002
75TH		L.003	L.003	L.002	.001	.0050	L.001	L.001	L.002
90TH		L.003	L.003	L.002	.003	.008	L.001	L.001	L.002
SECONDARY CODE									

		18150L DIELDRIN	18159L AROCLOR 1242 (PCB'S)	18160L AROCLOR 1254 (PCB'S)	18161L AROCLOR 1248 (PCB'S)	18162L AROCLOR 1260 (PCB'S)	18164L ARCCLORS TOTAL (PCB'S)	18180L BARBAN	18250L MALATHION
	SUBM ID	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
SAMPLES(FLAGS)	0060	162(162)	29(29)	90(90)	61(61)	90(90)	125(125)	70(70)	25(25)
LOW	0462	L.002	L.002	L.002	L.002	L.005	L.002	L.09	L.05
HIGH		L.002	L.002	L.032	L.024	L.06	L.020	L.1	L.05
AVERAGE									
STD.DEV.									
PERCNT:10TH		L.002	L.002	L.002	L.002	L.005	L.002	L.090	L.05
25TH		L.002	L.002	L.002	L.002	L.005	L.002	L.100	L.05
MEDIAN 50TH		L.002	L.002	L.002	L.002	L.005	L.002	L.100	L.05
75TH		L.002	L.002	L.002	L.02	L.005	L.002	L.100	L.05
90TH		L.002	L.002	L.030	L.02	L.060	L.002	L.100	L.05
SECONDARY CODE								80P	50P

		18340P DIMETHOATE	18360L DIALLATE	18363L TRIALLATE	18366L HOEGRASS (DICHLOFOP-METHYL)	18368L ENDAVEN	18370L TRI-FLURALIN	18415L ATRAZINE TOTAL	18500L 2,4-D
	SUBM ID	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
SAMPLES(FLAGS)	0462	24(24)	55(55)	55(55)	55(55)	55(55)	71(69)	55(54)	174(108)
LOW		L.01	L.10	L.01	L.05	L.025	L.005	L.05	L.002
HIGH		L.01	L.1	L.01	L.05	L.025	1.14	.10	.755
AVERAGE							.022*	.08*	.024*
STD.DEV.							.135*	.03*	.061*
PERCNT:10TH		L.01	L.10	L.01	L.05	L.025	L.005	L.05	L.004
25TH		L.01	L.10	L.01	L.05	L.025	L.005	L.05	L.004
MEDIAN 50TH		L.01	L.10	L.01	L.05	L.025	L.005	L.10	.010
75TH		L.01	L.1	L.01	L.05	L.025	L.005	L.10	L.030
90TH		L.01	L.1	L.01	L.05	L.025	L.01	L.10	.04
SECONDARY CODE		40L	60P	63P	66P	68P	70P	15P	00P 03P

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BATTLE RIVER NEAR UNWIN, SASKATCHEWAN

		18510L 2,4,5-T	18516P 2,4,-DP	18520L MCPA	18524L MCPB	18530P DIACAMBA	18535P 2,3,6,-TBA	18540L SILVEX	18549P 2,4,-DB
	SUBM ID	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
SAMPLES(FLAGS)	0462	173(170)	155(151)	155(151)	62(60)	62(61)	62(62)	138(137)	154(153)
LOW		L.002	L.004	L.03	L.05	L.03	L.03	L.004	L.009
HIGH		L.05	.06	.3	.11	.05	L.03	.055	.090
AVERAGE		.012*	.010*	.13*	.05*	.03*		.011*	.019*
STD.DEV.		.020*	.012*	.08*	.01*	.00*		.012*	.018*
PERCNT:10TH		L.002	L.004	L.03	L.05	L.03	L.03	L.004	L.009
25TH		L.002	L.004	L.03	L.05	L.03	L.03	L.004	L.009
MEDIAN 50TH		L.002	L.004	L.2	L.05	L.03	L.03	L.004	L.009
75TH		L.002	.004	L.20	L.05	L.03	L.03	L.030	L.009
90TH		L.050	L.030	L.20	L.05	L.03	L.03	L.030	L.050
SECONDARY CODE		10P 13P	55L 55P	20P 23P 23L	24P	30L	35L	40P 41P	50L 50P

		18599P PICLORAM	18600L PICLORAM (TORDON)	19103L POTASSIUM DISSOLVED	20101L CALCIUM DISSOLVED	23002P VANADIUM TOTAL	23301P VANADIUM EXTRBLE.	24002P CHROMIUM TOTAL	24302P CHROMIUM EXTRBLE.
	SUBM ID	UG/L	UG/L	K MG/L	CA MG/L	V MG/L	V MG/L	CR MG/L	CR MG/L
SAMPLES(FLAGS)	0001	59(54)	60(60)	199(3)	198(0)	118(25)	38(19)	82(30)	66(66)
LOW	0060	L.050	L.2	1.38	22.	L.0005	L.001	L.0003	L.001
HIGH	0462	.110	L.2	11.30	128.0	.0300	.007	.0223	L.015
AVERAGE		.053*		8.10	56.4	.0029*	.002*	.0019*	
STD.DEV.		.012*		1.40	20.3	.0051*	.001*	.0035*	
PERCNT:10TH		L.050	L.20	6.4	33.0	L.0005	L.001	.0003	L.015
25TH		L.050	L.20	7.3	40.7	.0009	L.001	.0006	L.015
MEDIAN 50TH		L.050	L.20	8.00	53.6	.0013	.001*	L.0010	L.015
75TH		L.05	L.20	9.00	69.2	.0022	.002	.0011	L.015
90TH		L.05	L.20	10.	85.5	.005	.004	.0035	L.015
SECONDARY CODE		99L	00P 01P		03L	20P 20L 02L	02P	03L 02L 03P	02L

		25104P MANGANESE DISSOLVED	25304P MANGANESE EXTRBLE.	26104L IRON DISSOLVED	26304L IRON EXTRBLE.	27002P COBALT TOTAL	27302P COBALT EXTRBLE.	28002P NICKEL TOTAL	28302P NICKEL EXTRBLE.
	SUBM ID	MN MG/L	MN MG/L	FE MG/L	FE MG/L	CO MG/L	CO MG/L	NI MG/L	NI MG/L
SAMPLES(FLAGS)	0060	124(33)	72(0)	108(24)	72(0)	122(67)	25(17)	119(4)	9(3)
LOW	0462	L.002	.010	.011	.06	L.0005	L.001	L.002	L.002
HIGH		1.560	1.7	.633	6.6	.009	.005	.036	.007
AVERAGE		.100*	.2063	.089*	.88	.0018*	.002*	.0066*	.004*
STD.DEV.		.239*	.3262	.122*	1.08	.0016*	.001*	.0059*	.002*
PERCNT:10TH		.005	.026	.022	.21	L.0005	L.002	.0025	
25TH		L.010	.0605	.034	.29	.0009	L.002	.0035	L.002
MEDIAN 50TH		L.020	.1000	L.040	.46	.0011	L.002	.0048	.004
75TH		.062	.2190	.077	1.10	L.0020	.002	.0070	.005
90TH		.240	.32	.240	2.4	.0030	.004	.011	
SECONDARY CODE		04F 04L			04P	20P 20L 02L		20P 20L 02L	

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BATTLE RIVER NEAR UNWIN, SASKATCHEWAN

	SUBM ID	29005P COPPER TOTAL	29305P COPPER EXTRBLE.	30005P ZINC TOTAL	30304P ZINC EXTRBL.	33104L ARSENIC DISSOLVED	24002L CHROMIUM TOTAL	34102L SELENIUM DISSOLVED	36001L COLIFORMS TOTAL
		CU	CU	ZN	ZN	AS	CR	SE	MPN
		MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	NO/100ML
SAMPLES(FLAGS)	0060	121(3)	67(12)	118(2)	68(19)	179(9)	82(30)	158(82)	140(19)
LOW	0462	.0008	L.001	L.001	L.001	.0003	L.0003	L.0000	L2.
HIGH		.0410	.017	.0560	.030	.0039	.0223	.0006	800.
AVERAGE		.0052*	.0034*	.0071*	.0045*	.0013*	.0019*	.0004*	74.*
STD.DEV.		.0059*	.0034*	.0102*	.0063*	.0008*	.0035*	.0002*	131.*
PERCNT:10TH		.0015	L.001	.0012	L.001	.0005	.0003	.0001	L2.
25TH		.0020	.001	.0020	L.0010	.0007	.0006	.0002	8.
MEDIAN 50TH		.0030	.002	.0040	.0020	.0011	L.0010	.0004	25.
75TH		.0050	.005	.007	.0045	.0018	.0011	L.0005	80.
90TH		.0130	.007	.0140	.012	.0025	.0035	L.0005	180.
SECONDARY CODE		20P 20L 05L		20P 20L 05L	05P	08L	03L 02P 03P	08L	02F 02L

	SUBM ID	36011F COLIFORMS FECAL	47301P SILVER EXTRBLE.	48002P CADMIUM TOTAL	48302P CADMIUM EXTRBLE.	56001P BARIUM TOTAL	56301P BARIUM EXTRBLE.	80011L MERCURY TOTAL	82002P LEAD TOTAL
		MPN	AG	CD	CD	BA	BA	HG	PB
		NO/100ML	MG/L	MG/L	MG/L	MG/L	MG/L	UG/L	MG/L
SAMPLES(FLAGS)	0060	187(41)	29(29)	122(110)	51(40)	122(33)	54(9)	131(108)	122(73)
LOW	0462	L2.	L.004	L.0001	L.001	L.05	L.05	L.01	L.0007
HIGH		11000.	L.01	.0041	.003	.270	.19	.07	.0550
AVERAGE		126.*		.0007*	.001*	.115*	.090*	.02*	.0028*
STD.DEV.		840.*		.0005*	.000*	.044*	.034*	.01*	.0052*
PERCNT:10TH		L2.	L.004	L.0001	L.001	L.080	L.05	L.01	L.0007
25TH		4.	L.004	L.0001	L.001	.082	.05	L.02	L.0010
MEDIAN 50TH		18.	L.004	L.0010	L.001	.100	.090	L.02	.0013
75TH		46.	L.004	L.0010	L.001	.132	.12	L.02	L.004
90TH		93.	L.006	L.0010	.002	.181	.13	.02	L.004
SECONDARY CODE		12L 12F		20P 20L 02L		20P 20L 01L	01L	11P	20P 20L 02L

	SUBM ID	82301P LEAD EXTRBLE.	96360P BROMOXYNIL
		PB	
		MG/L	UG/L
SAMPLES(FLAGS)	0060	68(58)	27(27)
LOW	0462	.003	L.03
HIGH		L.06	L.03
AVERAGE		.0050*	
STD.DEV.		.0068*	
PERCNT:10TH		L.004	L.03
25TH		L.0040	L.03
MEDIAN 50TH		L.0040	L.03
75TH		L.0040	L.03
90TH		.004	L.03
SECONDARY CODE		02P	

* THESE STATISTICS INCLUDE VALUES FLAGGED WITH L,G OR Q

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Appendix 6. Summary of QA/QC data for 1989-1990 surveys

APPENDIX 6. QUALITY ASSURANCE OF 1989-1990 SURVEY DATA.

Standard field and laboratory procedures were applied in the collection and processing of water samples from the Battle River (EQMB no date, Environment Canada 1988). Data were scrutinized by sampler and project manager prior to their transfer to the NAQUADAT system. As a result of this screening procedure, problems which justified the rejection of the data were noted for dissolved zinc and barium. Contamination by filters considerably increased concentrations of dissolved zinc and barium. To reduce the introduction of errors by manual transfer, data transfer to and from the NAQUADAT system was preformed electronically.

Laboratory quality control and quality assurance performances are discussed in Dieken et al. 1989. In addition, some quality assurance measures were initiated in the field. These consisted of the collection of duplicate and blank samples. These samples were handled according to the same routine procedures in the field and in the lab as regular samples and they were not identified to the lab.

Five duplicate sets of samples were taken from three sites during the 1989-1990 surveys. Duplicate samples consisted of two samples taken from the same location a few minutes apart and covered most water quality variables. Variability between these samples provides a joint measure of natural variability among river samples and of variability resulting from sampling, handling or analytical errors.

For most water quality variables, duplicate samples yielded values which differed by less than 10% (Table 6.1). However, for some constituents variability was much larger. This applies to some duplicate samples for BOD, silica, particulate carbon and tannin and lignin, and to most duplicate samples for dissolved and total aluminum and iron.

Two complete sets of field blank samples were analyzed for the same water quality variables as duplicate samples. Field blanks were obtained by filling regular sample containers with nanopure water from the analytical laboratory under typical field conditions. These samples provide an indication of error which may occur as a result of sample handling or analysis. Data for field blank samples were mostly below or at the analytical detection limit (Table 6.1). However some samples contained higher levels of BOD, NFR, carbon (particulate and dissolved), phosphorus (total and particulate), ammonia, Kjeldahl nitrogen and dissolved and total aluminum and iron.

Quality assurance samples indicate that natural variability in river water quality coupled with errors associated with sampling, sample handling and analysis may influence constituent concentrations. In a large data set such as that collected during the 1989-90 surveys, some values may be an under or over estimate of actual instream concentrations depending on various error combinations. However, the probability of occurrence of such errors is similar at all sites and it is unlikely that errors would result in consistent trends in water quality among surveys and among related variables. Therefore, emphasis was placed on delineating such trends. Site-to-site differences in constituent concentrations are discussed only if they coincide with specific events and if similar differences occurred in other related constituents.

DATA (cont.)

STATION	CODE	DATE	TEMP.	PH	ALKAL. TOTAL	HARD. TOTAL	SPEC. COND.	TDS	Ca	Mg	Na	K	HC03	CO3	Cl	SO4
		D/M/Y	DEG. C		mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
			02061F	10301F	10101L	10605L	02041L	00205L	20107L	12105L	11103L	19103L	06202L	06302L	17203L	16306L
A. DUPLICATE SAMPLES.																
BATTLE RIVER (SITE 10) AT HWY 872	00AL05FC1000	26-Jul-89	22	8.3	211	147	570	338	34	15	67	10	234	12	13.3	72
		26-Jul-89			210	147	570	340	34	15	67	9.9	238	9	13.2	74
		24-Oct-89	6.8	8.3	289	227	898	562	48	26	114	10.4	333	10	19.3	171
		24-Oct-89			288	223	899	567	48	25	116	10.5	332	9	19.4	175
BATTLE RIVER AT HWY 41	00AL05FE0400	11-Jan-90	0.3	7.8	410	329	1086	677	74	35	130	10.3	500		24	155
		11-Jan-90			408	331	1078	670	75	35	126	10.4	497		23.2	153
		30-Aug-90														
		30-Aug-90														
BATTLE RIVER (SITE 3) NEAR HWY 2A	00AL05FA0413	22-May-90	13.3	8.5	245		517	297	46	17	46	5.2	292	3	6.9	28
		22-May-90	13.3	8.5	236		498	285	44	16	44	5.2	281	3	6.8	26
B. BLANK SAMPLES																
(NANOPURE WATER FROM AEC)		12-Oct-90		5.91	2	7	1	7	L0.5	L0.5	L1	L0.1	2		L0.5	L3
		30-May-90		5.92	2	7	L1	7	L1	L0.5	L1	L0.1	2		L0.5	L3

STATION	CODE	DATE	F	SILICA REACT.	DO	DO	BOD	COD	NFR	FR	TURB.	COLOUR TRUE	DISS. C	PART. C	PART. P	TOTAL P	DISS. N-NH3
		D/M/Y	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	RCU	mg/L	mg/L	mg/L	mg/L	mg/L
			09107L	14107L	08101L	08102F	08202L	08304L	10401L	10451L	02074L	02024L	06107L	06905L	15901L	15421L	07562L
A. DUPLICATE SAMPLES.																	
BATTLE RIVER (SITE 10) AT HWY 872	00AL05FC1000	26-Jul-89	0.24	6.6		9	2	30	14	412		48	15		0.07	0.106	0.042
		26-Jul-89	0.25	6.6			1.8	36	12	400		41	15.5	3.65	0.07	0.106	0.037
		24-Oct-89	0.26	2.2		12.1	2.4	34	18	610		23	11.7	0.44	0.02	0.031	0.018
		24-Oct-89	0.26	2.2			1.8	32	10	604		22	12	0.18	0.02	0.03	0.015
BATTLE RIVER AT HWY 41	00AL05FE0400	11-Jan-90	0.31	14.4	4.76	4	1.6	35	6	724		29	14.9	0.35	0.03	0.076	0.38
		11-Jan-90	0.3	13.8			1.3	37	6	736		30	15.7	0.38	0	0.08	0.38
		30-Aug-90											13.7	2.41	0.09	0.101	0.016
		30-Aug-90											13.4	2.33	0.08	0.097	0.011
BATTLE RIVER (SITE 3) NEAR HWY 2A	00AL05FA0413	22-May-90	0.18	1.6	12.05		4.9		6	330	5.1	40	12.3	1.45		0.34	0.23
		22-May-90	0.18	2.3	12.1	13.4			8	328	7.3	29	11.9	1.55	0.09	0.335	0.24
B. BLANK SAMPLES																	
(NANOPURE WATER FROM AEC)		12-Oct-90	L0.01	L0.1			0.6	L4	4	L1	L0.1	L1	L0.2	0.09	L0.002	0.001	0.003
		30-May-90	L0.01	L0.1			0.56	L4	10	L1	L0.1	L1	0.6	0.06	0.002	0.003	0.024

APPENDIX 6.1 QUALITY ASSURANCE OF 1989-90 SYNOPTIC SURVEY DATA (cont.)

STATION	CODE	DATE D/M/Y	N-NO3+ N02 mg/L 07105L	N-NO2 mg/L 07205L	N-DISS. KJELD-N mg/L 07017L	N-PART. KJELD-N mg/L 07920L	TKN mg/L 07021L	N-PART TOTAL mg/L 07906L	PLANK. CHL-a mg/m3 06715L	TOTAL COLIF. #/100mL 36001L	FECAL COLIF. #/100mL 36011L	TAN. & LIGN. mg/L 06551L	OIL AND GREASE mg/L 06524L	PHENOL-IC MAT. mg/L 06537L	Al Ext. 13030L	Al Diss. 13109L	As Total 33005L
A. DUPLICATE SAMPLES.																	
BATTLE RIVER (SITE 10) AT HWY 872	00AL05FC1000	26-Jul-89	0.008	0.002	0.79	0.37	1.16		6.8			0.81	L1.0	0.008	0.157	0.083	0.002
		26-Jul-89		0.002	0.83	0.37	1.2	0.19				0.83	L1.0	0.008	0.096	0.017	0.0027
		24-Oct-89	0.002	0.001	0.64	0.1	0.74	0.03	3.1			0.51	L1.0	0.005	0.048	0.012	0.0012
		24-Oct-89	0.001	0.001	0.65	0.1	0.75	0.02				0.51	L1.0	0.005	0.039	0.021	0.0013
BATTLE RIVER AT HWY 41	00AL05FE0400	11-Jan-90	0.46	0.014	1.39	0.08	1.47	0.07	2	32	L4.	0.73	L1.0	0.005	0.027	0.014	0.0028
		11-Jan-90	0.45	0.013	1.37	0.09	1.46	0.05				0.32	L1.0	0.006	0.025	0.014	0.0027
		30-Aug-90	0.003	0.001	0.82	0.3	1.12	0.28	15.8	50	20				0.144	0.007	0.0026
		30-Aug-90	0.002	0.001	0.78	0.35	1.13	0.33							0.139	0.013	0.0027
BATTLE RIVER (SITE 3) NEAR HWY 2A	00AL05FA0413	22-May-90	0.13	0.044			1.46	0.24		190	10				0.023		0.0026
		22-May-90	0.142	0.037	1	0.44	1.44	0.25	50.3	270	44				0.024		0.0018
B. BLANK SAMPLES																	
(NANOPURE WATER FROM AEC)		12-Oct-90	L0.001	L0.001	L0.01	0.01	0.01	0.08	0	L4	L4	L0.05	L0.05	L0.001	0.01	L0.002	L0.0001
		30-May-90	0.001	L0.001	L0.01	0.02	0.02	L0.02	0	L4	L4	L0.05	L1	L0.001	0.006	0.022	L0.0001

STATION	CODE	DATE D/M/Y	As Diss. 33102L	Ba Total 56009L	Be Diss. 04103L	Cd Total 48009L	Cd Diss. 48109L	Co Total 27009L	Co Diss. 27109L	Cr Total 24009L	Cr Diss. 24109L	Cu Total 29009L	Cu Diss. 29109L	Pb Ext. 82301L	Pb Diss. 82103L	Hg Total 80015L	Mo Total 42009L
A. DUPLICATE SAMPLES.																	
BATTLE RIVER (SITE 10) AT HWY 872	00AL05FC1000	26-Jul-89	0.0023	0.087	L.001	0.002	0.001	0.002	0.001	0.003	0.002	0.004	0.003	L.002	L.002	L.0001	0.003
		26-Jul-89	0.004	0.086	L.001	L.001	0.002	0.003	L.001	0.002	0.002	0.01	0.003	L.002	L.002	L.0001	0.005
		24-Oct-89	0.001	0.066	L.001	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.002	L.002	0.003	L.0001	0.003
		24-Oct-89	0.0009	0.066	L.001	0.001	0.002	0.001	0.001	0.002	0.002	0.002	0.002	L.002	0.002	L.0001	0.003
BATTLE RIVER AT HWY 41	00AL05FE0400	11-Jan-90	0.0017	0.115	L.001	0.002	0.002	0.001	0.002	0.002	0.003	0.002	0.002	L.002	L.002	0.0001	0.003
		11-Jan-90	0.0016	0.11	L.001	0.003	0.002	0.001	0.001	0.003	0.002	0.002	0.002	L.002	L.002	L.0001	0.004
		30-Aug-90	0.0014	0.11	L.001	0.002	0.002	0.002	L.001	0.003	0.002	0.005	0.003	L.002	L.002	L.0001	0.003
		30-Aug-90	0.0015	0.109	L.001	0.002	0.002	0.001	L.001	0.004	0.003	0.004	0.003	L.002	L.002	L.0001	0.003
BATTLE RIVER (SITE 3) NEAR HWY 2A	00AL05FA0413	22-May-90		0.07	L.001	0.001		L.001		0.003		L.001		L.002		L.0001	L.001
		22-May-90		0.073	L.001	0.001		0.001		0.003		0.001		L.002		L.0001	0.001
B. BLANK SAMPLES																	
(NANOPURE WATER FROM AEC)		12-Oct-90	L0.0001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	0.001	L0.001	L0.002	L0.002	L0.0001	0.002
		30-May-90	L0.0001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	0.002	0.002	L0.0001	L0.001

DATA (cont.)

STATION	CODE	DATE D/M/Y	Mo Diss. 42109L	Mn Total 25004L	Mn Diss. 25109L	Ni Total 28009L	Ni Diss. 28109L	Fe Total 26009L	Fe Diss. 26109L	Zn Total 30009L	V Total 23009L	V Diss. 23109L	Se Total 34005L	Se Diss. 34102L
A. DUPLICATE SAMPLES.														
BATTLE RIVER (SITE 10) AT HWY 872	00AL05FC1000	26-Jul-89	0.003	0.103	0.012	0.006	0.006	0.988	0.025	0.006	0.005	0.003	L.0001	L.0001
		26-Jul-89	0.002	0.114	0.012	0.26	0.009	1.568	0.006	0.007	0.005	0.003	L.0001	L.0001
		24-Oct-89	0.003	0.065	0.046	0.007	0.007	0.338	0.045	0.001	0.004	0.004	L.0001	0.0001
		24-Oct-89	0.004	0.062	0.044	0.007	0.008	0.307	0.019	0.001	0.003	0.003	0.0001	0.0001
BATTLE RIVER AT HWY 41	00AL05FE0400	11-Jan-90	0.003	0.087	0.077	0.008	0.01	0.488	0.02	L.001	0.003	0.003	0.0001	0.0002
		11-Jan-90	0.003	0.085	0.078	0.007	0.008	0.468	0.023	L.001	0.003	0.003	0.0001	0.0001
		30-Aug-90	0.003	0.13	0.002	0.008	0.005	1.242	0.057	0.013	0.005	0.003	0.0001	L.0001
		30-Aug-90	0.002	0.126	0.002	0.007	0.008	1.238	0.111	0.007	0.005	0.004	0.0001	0.0001
BATTLE RIVER (SITE 3) NEAR HWY 2A	00AL05FA0413	22-May-90		0.046		0.005		0.325		0.001	0.003		0.0001	
		22-May-90		0.059		0.005		0.386		0.003	0.003		0.0001	
B. BLANK SAMPLES														
(NANOPURE WATER FROM AEC)		12-Oct-90	0.001	L0.001	L0.001	0.002	L0.001	0.005	0.02	0.001	L0.002	L0.002	L0.0001	L0.0001
		30-May-90	L0.001	L0.001	L0.001	0.001	0.002	L0.001	L0.001	L0.001	L0.002	L0.002	L0.0001	L0.0001

Appendix 7. Average daily mass loads (kg/d) at Battle River mainstem sites (May 1989-April 1990) and mainstem and tributary sites (April 1990-October 1990)

APPENDIX 7: AVERAGE DAILY MASS LOAD (KG/D) AT BATTLE RIVER MAINSTEM SITES (MAY 1989 - APRIL 1990) AND MAINSTEM AND TRIBUTARY SITES (APRIL 1990 - OCTOBER 1990)

A. MASSLOAD AT MAINSTEM SITES (MAY 1989 TO APRIL 1990)

STATION	CODE	Disch.	Alk. Total	Hard. Total	TDS	Ca	Mg	Na	K	HCO3	Cl	SO4	F	Si	BOD	COD
		97160S	10101L	10605L	00205L	20107L	12105L	11103L	19103L	06202L	17203L	16306L	09107L	14107L	08202L	08304L
HWY 611 (SITE 1)	00AL05FA0250	2.023	31354	23816	33845	6183	2032	3977	596	38215	433	1704	17	470	437	5790
HWY 53 (SITE 2)	00AL05FA0280	3.790	68602	52720	75479	13098	4871	9373	1564	81045	1036	4339	37	782	982	13385
HWY 2A (SITE 3)	00AL05FA0413	5.074	96556	74417	110859	18413	6905	14686	2241	108174	2422	8110	63	986	1507	19344
D/S SAMSON L. (SITE 4)	00AL05FA0500	4.896	80161	54622	98457	11421	6345	16709	2808	81325	3210	9729	70	1856	2892	28924
HWY 21 (SITE 5)	00AL05FA0700	7.277	127631	89986	177850	19726	9902	31750	4943	148771	7655	26956	127	2232	3843	42832
D/S CAMROSE CR. (SITE 6)	00AL05FA0750	7.574	135207	99872	193691	22575	10552	34190	5096	161873	8057	31818	124	2855	3215	43106
HWY 850 (SITE 7)	00AL05FA1000	7.532	139756	106648	208170	24893	10819	35305	6215	158385	9680	36932	142	3937	3693	47670
U/S FORESTBURG RES. (SITE 8)	00AL05FC0660	7.817	141241	106374	226509	25074	10637	42127	6593	162009	9295	47784	150	4525	3369	36640
HWY 861 (SITE 9)	00AL05FC0680	8.770	154577	112049	257628	25479	11745	50862	7265	183086	11536	57587	156	3107	3154	40444
HWY 872 (SITE 10)	00AL05FC1000	8.632	176159	138272	308167	30354	15140	59664	7383	204723	11955	76967	177	3282	2334	37589
D/S HARDISTY (SITE 11)	00AL05FB0500	9.017	197007	151529	319710	33110	16750	59891	6992	229533	13234	71187	171	3759	2396	37103
HWY 41 (SITE 12)	00AL05FE0400	9.033	211405	144676	333740	31120	16292	69558	6322	239306	13170	70045	169	4166	2449	31998
HWY 897 (SITE 13)	00AL05FE0850	10.453	259414	168879	427390	34205	20320	95502	7428	291361	17283	96631	201	3443	2732	45832
UNWIN (SITE 14)	00SA05FE1000	10.906	280446	187160	464543	37927	22497	102237	7809	315310	19776	105653	214	4358	3157	45936
HWY 40 (SITE 15)	00SA05FF1000	13.173	314543	227763	550985	45809	27599	116656	9475	350678	21880	140414	256	4638	3229	57617

B. MASSLOAD AT MAINSTEM AND TRIBUTARY SITES (APRIL 1990 TO OCTOBER 1990)

STATION	CODE	Disch.	Alk. Total	Hard. Total	TDS	Ca	Mg	Na	K	HCO3	Cl	SO4	F	Si	BOD	COD
		97160S	10101L	10605L	00205L	20107L	12105L	11103L	19103L	06202L	17203L	16306L	09107L	14107L	08202L	08304L
HWY 611 (SITE 1)	00AL05FA0250	4.043	65663	52653	71339	13622	4541	8121	1380	80071	777	3318	35	821	1284	11351
PIGEON L. CR.	00AL05FA0225	1.580	21978	18020	23617	4505	1638	2321	683	26756	287	956	15	1433	218	3276
HWY 53 (SITE 2)	00AL05FA0280	7.005	105613	86246	115751	21334	8019	12256	3601	128763	1286	5750	62	4100	2058	20275
WOLF CR.	00AL05FA0287	1.274	31811	28977	40617	7843	2284	4485	779	38801	1816	4183	25	864	454	4678
HWY 2A (SITE 3)	00AL05FA0413	9.720	138568	114494	156484	28274	10638	15956	5431	165722	2967	9238	98	5459	3107	29953
D/S SAMSON L. (SITE 4)	00AL05FA0500	6.575	109781	86064	132079	21161	8095	17184	4062	127960	3380	11930	87	1150	2556	27126
PIPESTONE CR.	00AL05FA0600	4.520	81225	60236	107877	15425	5272	16987	3759	99091	4257	13277	82	1728	2128	22356
HWY 21 (SITE 5)	00AL05FA0700	11.415	201443	156322	250016	38711	14547	34519	7298	241633	6731	26875	160	2071	4931	48820
CAMROSE CR.	00AL05FA0745	0.652	11717	13464	33588	3098	1394	6380	780	14294	2812	11788	18	362	583	3845
D/S CAMROSE CR. (SITE 6)	00AL05FA0750	12.067	213209	173852	291664	42225	16681	41182	8184	255174	10947	43267	182	3180	5552	52390
HWY 850 (SITE 7)	00AL05FA1000	11.315	223874	186969	312593	44726	18330	45215	8847	271777	10534	49858	178	2346	6281	65745
MEETING CR.	00AL05FC0290	0.634	17265	9037	25645	2287	808	6298	501	21058	769	4573	13	351	214	2848
BIG KNIFE CR.	00AL05FC0400	0.036														
U/S FORESTBURG RES. (SITE 8)	00AL05FC0660	11.748	224321	186257	315166	44915	18017	46691	9161	271012	10759	50751	185	3908	5862	51259
HWY 861 (SITE 9)	00AL05FC0680	13.788	224557	190010	319562	46758	17869	45864	10334	265656	9500	53608	194	3187	5033	63436
PAINTEARTH CR.	00AL05FC0690	0.333	4901	3318	10549	901	259	2513	199	5975	226	3510	6	286	110	1285
CASTOR CR.	00AL05FC0800	0.168	1594	1001	3449	270	80	835	82	1944	73	1151	2	110	45	613
HWY 872 (SITE 10)	00AL05FC1000	13.633	225272	189640	324509	46821	17668	47410	10218	267381	8834	61631	200	3534	4770	66845
D/S HARDISTY (SITE 11)	00AL05FB0500	14.555	269745	225731	389212	55647	21064	57847	11004	324448	11255	64328	223	4779	4747	60991
IRON CR.	00AL05FB0700	0.781	32822	22646	57493	3341	3476	12943	947	38593	974	16099	12	770	243	4928
HWY 41 (SITE 12)	00AL05FE0400	15.458	311455	252156	434862	61436	24040	67046	10952	375296	10765	64381	240	7052	3980	60101
BUFFALO CR.	00AL05FE0500	0.100	5262	4260	9357	665	631	1944	49	6204	23	2886	2	85	20	449
GRIZZLY BEAR CR.	00AL05FE0600	0.003	217	145	426	12	28	105	4	228	10	137	0	0	1	29
HWY 897 (SITE 13)	00AL05FE0850	16.533	343889	276040	508870	66778	26783	84276	11927	407453	13356	98917	264	8856	4499	83205
RIBSTONE CR.	00AL05FE0875	0.433	12970	9611	15600	1900	1179	2602	197	15188	216	1722	11	256	78	1909
BLACKFOOT CR.	00AL05FE0890	0.003	143	121	312	18	18	64	4	163	2	120	0	1	1	13
UNWIN (SITE 14)	00SA05FE1000	17.430	368958	288013	541766	67768	28990	92240	12650	432208	13742	104664	294	10015	5949	80192

APPENDIX 7: AVERAGE DAILY MASS LOAD (KG/D) AT BATTLE RIVER MAINSTEM SITES (MAY 1989 - APRIL 1990) AND MAINSTEM AND TRIBUTARY SITES (APRIL 1990 - OCTOBER 1990)

A. MASSLOAD AT MAINSTEM SITES (MAY 1989 TO APRIL 1990)

STATION	CODE	NFR	FR	T&L	O&G	Phenol. Mat.	DOC	POC	Part. P	Tot.P	N-NH3	N-NO2+ N03	N-NO2	N-TKN	Part-N	Chla
		10401L	10451L	06551L	06524L	06537L	06107L	06905L	15901L	15421L	07562L	07105L	07205L	07021L	07906L	06715L
HWY 611 (SITE 1)	00AL05FA0250	1363	43350	127	59	1	1929	288	8	17	10	14	1	151	36	1477
HWY 53 (SITE 2)	00AL05FA0280	7200	95863	325	33	3	4523	712	22	58	22	16	2	393	92	2546
HWY 2A (SITE 3)	00AL05FA0413	5831	140176	463	44	5	6472	831	35	98	46	28	3	552	117	11146
D/S SAMSON L. (SITE 4)	00AL05FA0500	11517	132615	480	90	6	8143	2616	57	82	37	30	3	939	358	25941
HWY 21 (SITE 5)	00AL05FA0700	45024	263827	695	149	9	12009	3248	118	199	91	56	5	1287	394	23962
D/S CAMROSE CR. (SITE 6)	00AL05FA0750	41339	287346	824	221	9	12179	3673	120	172	121	41	3	1396	414	24702
HWY 850 (SITE 7)	00AL05FA1000	41032	282360	665	57	9	13056	5764	133	274	223	40	5	1560	733	38868
U/S FORESTBURG RES. (SITE 8)	00AL05FC0660	24998	291177	653	59	8	11465	3127	90	141	69	60	8	1218	403	37450
HWY 861 (SITE 9)	00AL05FC0680	55570	372329	723	332	8	11991	2314	112	162	85	87	11	1209	369	19824
HWY 872 (SITE 10)	00AL05FC1000	90548	436743	565	186	7	10935	2988	109	137	54	84	8	1044	298	15606
D/S HARDISTY (SITE 11)	00AL05FB0500	76134	448938	579	205	6	10410	4469	105	122	56	75	5	1035	283	17626
HWY 41 (SITE 12)	00AL05FE0400	78045	476953	575	263	5	9726	2791	108	135	59	73	4	965	317	16497
HWY 897 (SITE 13)	00AL05FE0850	187788	703738	693	226	7	12011	4383	151	173	65	67	5	1227	452	19157
UNWIN (SITE 14)	00SA05FE1000	180435	760536	724	365	7	13109	6829	196	218	66	73	4	1461	506	18928
HWY 40 (SITE 15)	00SA05FF1000	253484	875771	750	142	8	14966	7190	239	260	101	58	4	1756	666	22122

B. MASSLOAD AT MAINSTEM AND TRIBUTARY SITES (APRIL 1990 TO OCTOBER 1990)

STATION	CODE	NFR	FR	T&L	O&G	Phenol. Mat.	DOC	POC	Part. P	Tot.P	N-NH3	N-NO2+ N03	N-NO2	N-TKN	Part-N	Chla
		10401L	10451L	06551L	06524L	06537L	06107L	06905L	15901L	15421L	07562L	07105L	07205L	07021L	07906L	06715L
HWY 611 (SITE 1)	00AL05FA0250	5326	88366	296		3	2445	880	24	28	7	1	0	279	105	3248
PIGEON L. CR.	00AL05FA0225	8873	37131	40		0	1437	238	8	15	9	9	1	132	38	1546
HWY 53 (SITE 2)	00AL05FA0280	17098	160084	514		5	6204	1062	45	90	60	34	4	811	150	3041
WOLF CR.	00AL05FA0287	936	47001	120		1	1635	139	56	78	16	23	2	168	25	2149
HWY 2A (SITE 3)	00AL05FA0413	20715	228988	798		10	9133	1386	67	175	144	103	16	1067	206	7530
D/S SAMSON L. (SITE 4)	00AL05FA0500	15196	172412	609		7	7229	2207	60	101	81	67	5	861	301	15935
PIPESTONE CR.	00AL05FA0600	22649	158741	436		5	6726	1067	56	88	75	29	6	732	181	9870
HWY 21 (SITE 5)	00AL05FA0700	75202	381681	1105		11	13093	4658	158	217	165	98	6	1659	648	33163
CAMROSE CR.	00AL05FA0745	3746		74		1	1068	228	17	39	98	40	8	208	37	3504
D/S CAMROSE CR. (SITE 6)	00AL05FA0750	89402	437887	1209		12	14570	4593	211	285	306	180	18	2234	678	43606
HWY 850 (SITE 7)	00AL05FA1000	72832	444326	983		12	15275	7266	176	280	163	86	8	2134	958	55504
MEETING CR.	00AL05FC0290	3464	33189	77		1	916	176	7	11	8	9	1	86	23	437
BIG KNIFE CR.	00AL05FC0400			2		0	43	2	0	0	0	0	0	3	0	19
U/S FORESTBURG RES. (SITE 8)	00AL05FC0660	49990	419206	1012		10	15733	4535	137	169	146	47	5	1888	624	57628
HWY 861 (SITE 9)	00AL05FC0680	118235	543225	1272		11	18673	4092	185	238	133	174	14	1858	667	28740
PAINTEARTH CR.	00AL05FC0690	1659	15786	35		0	414	80	4	5	2	1	0	39	13	372
CASTOR CR.	00AL05FC0800	504	7168	14		0	194	11	0	1	0	0	0	12	2	100
HWY 872 (SITE 10)	00AL05FC1000	280927	653730	1278		10	17492	5059	230	275	132	97	9	1888	545	25236
D/S HARDISTY (SITE 11)	00AL05FB0500	184860	691025	1176		10	17354	5351	214	242	145	98	7	2172	588	26786
IRON CR.	00AL05FB0700	1890	65205	112		1	1728	176	8	25	4	1	0	147	26	1380
HWY 41 (SITE 12)	00AL05FE0400	171487	692894	1189		10	17730	5162	230	264	150	84	5	1856	618	14458
BUFFALO CR.	00AL05FE0500	78	10126	9		0	168	11	0	2	0	0	0	11	1	16
GRIZZLY BEAR CR.	00AL05FE0600	3	458	0		0	10	1	0	0	0	0	0	1	0	5
HWY 897 (SITE 13)	00AL05FE0850	493515	1054165	1346		11	18712	7113	357	391	153	87	5	2203	800	22319
RIBSTONE CR.	00AL05FE0875	571	18426	46		0	722	29	2	3	2	0	0	49	4	157
BLACKFOOT CR.	00AL05FE0890	3	334	0		0	4	1	0	0	0	0	0	0	0	2
UNWIN (SITE 14)	00SA05FE1000	456680	1169372	1385		11	20255	12646	474	517	178	108	6	2714	1129	22250

APPENDIX 7: AVERAGE DAILY MASS LOAD (KG/D) AT BATTLE RIVER MAINSTEM SITES (MAY 1989 - APRIL 1990) AND MAINSTEM AND TRIBUTARY SITES (APRIL 1990 - OCTOBER 1990)

A. MASSLOAD AT MAINSTEM SITES (MAY 1989 TO APRIL 1990)

STATION	CODE	Colif Total 36001L	Colif Fecal 36011L	Al Ext. 13030L	Al Diss 13109L	As Total 33005L	As Diss 33102L	Ba Total 56009L	Ba Diss 56109L	Cd Total 48009L	Co Total 27009L	Cr Total 24009L	Cu Total 29009L	Mo Total 42009L	Mn Total 25004L	Ni Total 28009L
HWY 611 (SITE 1)	00AL05FA0250	166607	2622	17	1	0	0	12	12	0	0	0	0	0	14	0
HWY 53 (SITE 2)	00AL05FA0280	328602	26360	21	4	1	1	25	23	0	0	1	1	1	19	1
HWY 2A (SITE 3)	00AL05FA0413	301176	11398	19	0	1	1	32	32	0	0	1	1	1	29	2
D/S SAMSON L. (SITE 4)	00AL05FA0500	463730	8672	14	5	1	1	26	24	0	0	1	0	1	23	1
HWY 21 (SITE 5)	00AL05FA0700	639859	45740	85	4	2	1	52	53	1	1	2	2	2	95	4
D/S CAMROSE CR. (SITE 6)	00AL05FA0750	657960	29446	54	18	2	1	52	44	1	1	2	2	2	100	4
HWY 850 (SITE 7)	00AL05FA1000	1461852	78094	35	14	2	1	50	52	1	1	2	1	2	119	4
U/S FORESTBURG RES. (SITE 8)	00AL05FC0660	95455	7333	40	20	3	2	61	72	1	1	2	2	2	104	4
HWY 861 (SITE 9)	00AL05FC0680	317640	26899	98	16	3	1	75	110	1	2	4	4	3	120	8
HWY 872 (SITE 10)	00AL05FC1000	176010	24612	81	50	3	1	73	87	1	2	3	4	3	117	7
D/S HARDISTY (SITE 11)	00AL05FB0500	68818	29994	135	9	3	1	77	73	1	2	3	4	3	139	8
HWY 41 (SITE 12)	00AL05FE0400	87411	21853	138	18	3	1	81	83	1	2	3	4	3	131	7
HWY 897 (SITE 13)	00AL05FE0850	141915	33415	224	18	4	1	99	94	2	3	4	6	3	173	9
UNWIN (SITE 14)	00SA05FE1000	111817	54888	277	20	5	1	111	82	2	3	4	6	4	192	11
HWY 40 (SITE 15)	00SA05FF1000	60320	36419	343	11	6	2	138	100	2	5	7	8	6	251	14

B. MASSLOAD AT MAINSTEM AND TRIBUTARY SITES (APRIL 1990 TO OCTOBER 1990)

STATION	CODE	Colif Total 36001L	Colif Fecal 36011L	Al Ext. 13030L	Al Diss 13109L	As Total 33005L	As Diss 33102L	Ba Total 56009L	Ba Diss 56109L	Cd Total 48009L	Co Total 27009L	Cr Total 24009L	Cu Total 29009L	Mo Total 42009L	Mn Total 25004L	Ni Total 28009L
HWY 611 (SITE 1)	00AL05FA0250	171143	23750	39	0	1	0	41	39	0	0	1	1	0	23	1
PIGEON L. CR.	00AL05FA0225	226815	6826	10	2	0	0	11	11	0	0	0	0	0	15	0
HWY 53 (SITE 2)	00AL05FA0280	1070353	49629	59	8	1	1	54	54	1	0	2	1	1	52	2
WOLF CR.	00AL05FA0287	218386	1211	3	1	0	0	12	12	0	0	0	0	0	18	1
HWY 2A (SITE 3)	00AL05FA0413	1104977	14697	65	4	1	1	72	71	1	0	3	1	1	76	4
D/S SAMSON L. (SITE 4)	00AL05FA0500	1229041	2556	37	6	1	1	45	44	1	0	1	1	0	39	2
PIPESTONE CR.	00AL05FA0600	320411	8201	69	4	1	0	39	32	1	1	2	1	1	62	3
HWY 21 (SITE 5)	00AL05FA0700	1628802	36491	183	8	2	1	83	79	1	2	4	4	2	223	8
CAMROSE CR.	00AL05FA0745	104028	3831	8	1	0	0	3	3	0	0	0	0	0	16	1
D/S CAMROSE CR. (SITE 6)	00AL05FA0750	1744599	21894	137	8	2	1	102	85	2	2	5	4	3	172	6
HWY 850 (SITE 7)	00AL05FA1000	2781318	40082	73	13	2	1	95	81	2	2	8	4	3	174	8
MEETING CR.	00AL05FC0290	59559	1314	4	0	0	0	6	7	0	0	0	0	0	9	1
BIG KNIFE CR.	00AL05FC0400	0	174	0	0	0	0	0	0	0	0	0	0	0	0	0
U/S FORESTBURG RES. (SITE 8)	00AL05FC0660	355260	5075	48	5	2	1	97	116	2	2	3	3	1	186	7
HWY 861 (SITE 9)	00AL05FC0680	1143632	25017	96	14	4	2	133	164	2	3	5	7	4	199	10
PAINTEARTH CR.	00AL05FC0690	66174	1056	3	1	0	0	3	4	0	0	0	0	0	7	0
CASTOR CR.	00AL05FC0800	3618	232	0	0	0	0	1	1	0	0	0	0	0	3	0
HWY 872 (SITE 10)	00AL05FC1000	481758	21202	119	11	4	1	150	151	2	4	5	9	4	229	12
D/S HARDISTY (SITE 11)	00AL05FB0500	293010	57847	339	25	4	1	161	136	2	4	6	9	5	245	14
IRON CR.	00AL05FB0700	58320	3240	11	0	0	0	4	5	0	0	0	0	0	9	1
HWY 41 (SITE 12)	00AL05FE0400	111787	42738	375	5	5	1	173	154	2	4	6	9	5	251	13
BUFFALO CR.	00AL05FE0500	1296	968	0	0	0	0	0	0	0	0	0	0	0	1	0
GRIZZLY BEAR CR.	00AL05FE0600	70	54	0	0	0	0	0	0	0	0	0	0	0	0	0
HWY 897 (SITE 13)	00AL05FE0850	98560	21426	534	9	6	2	209	190	4	6	7	11	6	343	19
RIBSTONE CR.	00AL05FE0875	6176	1160	5	0	0	0	4	4	0	0	0	0	0	2	0
BLACKFOOT CR.	00AL05FE0890	907	16	0	0	0	0	0	0	0	0	0	0	0	0	0
UNWIN (SITE 14)	00SA05FE1000	120476	60991	818	0	8	2	233	171	4	7	11	14	6	412	22

APPENDIX 7: AVERAGE DAILY MASS LOAD (KG/D) AT BATTLE RIVER MAINSTEM SITES (MAY 1989 - APRIL 1990) AND MAINSTEM AND TRIBUTARY SITES (APRIL 1990 - OCTOBER 1990)

A. MASSLOAD AT MAINSTEM SITES (MAY 1989 TO APRIL 1990)

STATION	CODE	Fe Total 26009L	Fe Diss. 26109L	Zn Total 30009L	V Total 23009L	Se Total 34005L
HWY 611 (SITE 1)	00AL05FA0250	67	21	1	0	0
HWY 53 (SITE 2)	00AL05FA0280	234	54	1	1	0
HWY 2A (SITE 3)	00AL05FA0413	244	85	1	1	0
D/S SAMSON L. (SITE 4)	00AL05FA0500	174	63	2	1	0
HWY 21 (SITE 5)	00AL05FA0700	1079	122	4	4	0
D/S CAMROSE CR. (SITE 6)	00AL05FA0750	1083	135	5	4	0
HWY 850 (SITE 7)	00AL05FA1000	602	52	3	3	0
U/S FORESTBURG RES. (SITE 8)	00AL05FC0660	563	59	4	3	0
HWY 861 (SITE 9)	00AL05FC0680	1545	160	8	5	0
HWY 872 (SITE 10)	00AL05FC1000	1951	192	11	6	0
D/S HARDISTY (SITE 11)	00AL05FB0500	1882	65	9	6	0
HWY 41 (SITE 12)	00AL05FE0400	1948	96	9	6	0
HWY 897 (SITE 13)	00AL05FE0850	3164	150	13	8	0
UNWIN (SITE 14)	00SA05FE1000	3918	163	15	10	0
HWY 40 (SITE 15)	00SA05FF1000	5630	188	21	14	0

B. MASSLOAD AT MAINSTEM AND TRIBUTARY SITES (APRIL 1990 TO OCTOBER 1990)

STATION	CODE	Fe Total 26009L	Fe Diss. 26109L	Zn Total 30009L	V Total 23009L	Se Total 34005L
HWY 611 (SITE 1)	00AL05FA0250	594	28	3	2	0
PIGEON L. CR.	00AL05FA0225	71	16	0	0	0
HWY 53 (SITE 2)	00AL05FA0280	585	90	3	2	0
WOLF CR.	00AL05FA0287	52	16	0	0	0
HWY 2A (SITE 3)	00AL05FA0413	650	139	3	3	0
D/S SAMSON L. (SITE 4)	00AL05FA0500	344	68	1	2	0
PIPESTONE CR.	00AL05FA0600	879	66	4	2	0
HWY 21 (SITE 5)	00AL05FA0700	1816	286	7	5	0
CAMROSE CR.	00AL05FA0745	108	7	1	0	0
D/S CAMROSE CR. (SITE 6)	00AL05FA0750	2347	188	11	7	0
HWY 850 (SITE 7)	00AL05FA1000	1150	65	9	5	0
MEETING CR.	00AL05FC0290	106	18	1	0	0
BIG KNIFE CR.	00AL05FC0400	2	0	0	0	0
U/S FORESTBURG RES. (SITE 8)	00AL05FC0660	1093	63	6	5	0
HWY 861 (SITE 9)	00AL05FC0680	3003	260	16	8	0
PAINTEARTH CR.	00AL05FC0690	108	20	1	0	0
CASTOR CR.	00AL05FC0800	10	1	0	0	0
HWY 872 (SITE 10)	00AL05FC1000	4598	378	23	11	0
D/S HARDISTY (SITE 11)	00AL05FB0500	4581	132	20	11	0
IRON CR.	00AL05FB0700	62	16	0	1	0
HWY 41 (SITE 12)	00AL05FE0400	4969	217	23	10	0
BUFFALO CR.	00AL05FE0500	3	1	0	0	0
GRIZZLY BEAR CR.	00AL05FE0600	0	0	0	0	0
HWY 897 (SITE 13)	00AL05FE0850	7748	371	30	14	0
RIBSTONE CR.	00AL05FE0875	27	6	0	0	0
BLACKFOOT CR.	00AL05FE0890	0	0	0	0	0
UNWIN (SITE 14)	00SA05FE1000	9992	481	43	18	0

Appendix 8. Summary of wastewater effluent data for 1989-1990

APPENDIX 8. SUMMARY OF WASTEWATER EFFLUENT DATA FOR 1989 - 1990.

MUNICIPALITY	POPULATION	DISCHARGE ROUTE	VOLUME DISCHARGE (m^3)		TOT. PHOSPHORUS (mg/L)		AMMONIA (mg/L)		BOD (mg/L)		NFR (mg/L)		SODIUM [D] (mg/L)	CHLORIDE [D] (mg/L)
			SPRING	FALL	SPRING	FALL	SPRING	FALL	SPRING	FALL	SPRING	FALL		
Mulhurst	165+	Ditch to Pipestone Creek	-	156 000	-	2.4[B]	-	2.8[B]	-	8[B]	-	22[B]	140	4
Lacombe	6 080	Wolf Creek	360 744	405 314	6.4[B]	3.9[B]	18.5[B]	5.8[B]	88	9	21	37	430	80
Ponoka	5 473	Battle River	786 131	786 131	6.4[B]	3.9[B]	18.5[B]	5.8[B]	14	3	42	19	213	47
Wetaskiwin	10 103	Town Creek & Pipestone Creek	761 802	645 976	10.5	8.5	62.8	12.3	15	54	69	25	177	77
Millet	1 540	Pipestone Creek	-	40 000	-	2.4[B]	-	2.8[B]	-	8[B]	-	22[B]	317	37
Gwynne	97	Pipestone Creek	-	16 400	-	2.4[B]	-	2.8[B]	-	8[B]	-	22[B]	-	-
Ferintosh	125	Meeting Creek	-	-	-	-	-	-	-	-	-	-	-	-
New Norway	278	Ditch to Battle River	32 850[A]	-	4.1[B]	-	10.6[B]	-	26[B]	-	34[B]	-	-	-
Bittern Lake	153	Bittern Lake	-	3 436	-	2.4[B]	-	2.8[B]	-	7.5	-	32	806	105
Hay Lakes	294	Ditch to Camrose Creek	-	57 617	-	2.4[B]	-	2.8[B]	-	6.0	-	74	452	76
Camrose	12 968	Camrose Creek	814 625	1 136 091	7.7	2.0	20.9	1.6	20	3	12	10	238	141
Ohaton	111	Creek	-	-	-	-	-	-	-	-	-	-	-	-
Edberg	124	Creek	-	9 090	-	2.4[B]	-	2.8[B]	-	24	-	76	348	57
Stettler	5 147	Red Willow Creek	294 058	338 545	6.4[B]	3.9[B]	18.5[B]	5.8[B]	52[B]	14[B]	40[B]	32[B]	-	-
Botha	176	Creek	-	14 914	-	2.4[B]	-	2.8[B]	-	34[B]	-	14[B]	-	-
Donalda	237	Meeting Creek	-	16 000	-	2.4[B]	-	2.8[B]	-	4.3	-	5.2	-	-
Rosalind	214	Driedmeat Creek	-	-	-	-	-	-	-	-	-	-	143	100
Bawlf	375	Driedmeat Creek	-	32 850[A]	-	2.4[B]	-	2.8[B]	-	8[B]	-	22[B]	920	140
Daysland	678	Driedmeat Creek	-	136 350	-	2.4[B]	-	2.8[B]	16	4	5	17	820	150
Halkirk	155	Paintearth Creek	-	-	-	-	-	-	-	-	-	-	-	-
Heisler	209	Slough	-	2 220	-	2.4[B]	-	2.8[B]	-	8	-	22	470	50
Strome	267	Ditch to Wavy Lake	-	44 435	-	2.4[B]	-	2.8[B]	-	5	-	22	-	-
Viking	1 160	Thomas Lake	-	4 812	-	2.4[B]	-	2.8[B]	-	21.4	-	22[B]	469	160
Killam	1 032	Creek/Ditch to Battle River	-	99 280	-	2.4[B]	-	2.8[B]	-	8[B]	-	22[B]	475	275
Forestburg	936	Creek to Battle River	-	21 647	-	2.4[B]	-	2.8[B]	-	10	-	4	580	296
Galahad	176	Slough to Battle River	-	35 885	-	2.4[B]	-	2.8[B]	-	8	-	22	633	550
Castor	1 030	Castor Creek	-	154 030	-	2.4[B]	-	2.8[B]	-	3	-	10	-	-
Alliance	202	Creek to Battle River	14 000[A]	14 000[A]	6.4[B]	3.9[B]	18.5[B]	5.8[B]	32	17	41	22	212	38
Lougheed	268	Iron Creek	70 080[A]	-	4.1[B]	-	10.6[B]	-	17	-	34	-	679	275
Sedgewick	877	Iron Creek	-	-	-	-	-	-	-	-	-	-	175	149
Kinsella	69	Slough	-	-	-	-	-	-	-	-	-	-	-	-
Irma	484	Grattan Creek	-	91 640	-	2.4[B]	-	2.8[B]	-	3[B]	-	3[B]	505	65
Hardisty	642	Ditch to Battle River	-	-	-	-	-	-	-	-	-	-	156	170
Coronation	1 310	Ribstone Creek	35 632	81 810	6.4[B]	3.9[B]	18.5[B]	5.8[B]	52[B]	40[B]	14[B]	32[B]	710	72
Veteran	312	Slough	37 900	-	4.1[B]	-	10.6[B]	-	26	-	34	-	-	-
Czar	186	Ribstone Creek	-	27 270	-	2.4	-	2.8[B]	-	58.6	-	41.3	-	-
Hughenden	276	Hughenden Lake	-	-	-	-	-	-	-	-	-	-	-	-
Amisk	217	-	-	-	-	-	-	-	-	-	-	-	-	-
Wainwright	4 665+	Bushy Head Lake to Battle River	1 040 688	(cont)	1.97[C]	1.97[C]	1.20[C]	1.20[C]	3[C]	3[C]	10[C]	10[C]	844	245
Greenshields	50	-	-	-	-	-	-	-	-	-	-	-	-	-
Fabyan	100	Ditch to Battle River	-	-	-	-	-	-	-	-	-	-	-	-
Metiskow	85	Slough	-	-	-	-	-	-	-	-	-	-	-	-
Edgerton	399	Slough	-	-	-	-	-	-	-	-	-	-	-	-
Paradise Valley	185	Bricker Lake	-	-	-	-	-	-	-	-	-	-	-	-

+ Population much larger at some times of the year (tourism, military base camp); - = No data; [A] = Estimate based on population density and average water consumption (Browning 1988); [B] = Based on Beier (1987) taking release frequency and time of year into consideration; [C] = Water is pumped continuously from Bushy Head Lake to the Battle River (33 L/s), "effluent" concentrations are averages for the lake; [D] = Alberta Environment (1991)